Light Regional Council

WASLEYS STORMWATER MANAGEMENT PLAN

November 2010

LIGHT REGIONAL COUNCIL

Government of South Australia

Adelaide and Mount Lofty Ranges Natural Resources Management Board

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Australian WATER Environments

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Executive Summary

Introduction

Light Regional Council (Council) engaged Australian Water Environments (AWE) in September 2009 to develop a Stormwater Management Plan (SMP) for the township of Wasleys.

The main scope of the Wasleys SMP study was to:

- Build a better understanding of the current drainage regime of the township;
- Develop strategies to alleviate existing drainage problems;
- Identify potential opportunities for reuse of stormwater; and
- Assess the flood risk from Templers Creek.

Council was successful in gaining the support and financial contributions for preparing the Plan from the Adelaide and Mount Lofty Ranges Natural Resources Management Board (AMLR NRMB) and the Stormwater Management Authority (SMA), for the amounts of $20,000 and $10,000 respectively.

Stormwater Issues and Management Objectives

Consultation with the community and discussions with the project steering committee (representatives from Light Regional Council, the AMLR NRMB and the SMA) were undertaken early in the project to identify stormwater issues and objectives for the Wasleys SMP. The process involved AWE developing a consultation strategy and then undertaking (with Council) meetings with community group representatives and as well as with long term residents who were able to provide historical information on flooding issues. The process also included preparation of a community survey, reviewing feedback and the preparation of a letter to interested residents and community groups summarising the findings of the SMP.

The following key stormwater management issues were raised through the consultation process:

- There is persistent pooling of water in some streets, particularly some local/access streets, during winter months, and this has become worse over time;
- There are obstructions in road side swales which exacerbate flooding;
- Some sections of the township do not have any formalized drainage infrastructure;
- There is a desire to prevent property damage due to flooding;
- There is a desire to ensure new housing developments have appropriate finished floor levels to safeguard against flooding from Templers Creek;
- There is a desire to ensure flood control embankments are maintained adequately and to appropriate performance standards; and
- There is a desire to reuse stormwater to irrigate public/community areas in Wasleys.

Through the above consultation process and technical assessments the following stormwater management objectives were developed for Wasleys, including:

- Reduce the impact of nuisance local flooding, such as pooling water along streets;
- Provide an acceptable level of protection of assets from local and regional flooding (Templers Creek);
- Manage stormwater to benefit the community through greening of public open space;

- Minimise adverse impacts on downstream environments resulting from stormwater management and water harvesting activities;
- Use the planning system to achieve desirable outcomes for new developments, open spaces, recreation and local amenity;
- Assess stormwater management options and rank their priority in accordance with the format recognized in the SMA/ NRM SMP guidelines with verification against Council wide assessment criteria; and
- Manage rural catchment contributions such that the management, control and harvesting of both rural and urban runoff is efficient and effective.

The SMP addressed these objectives through the use of hydrological, hydraulic and water balance modelling and by considering the anecdotal evidence available regarding the performance of the system.

Understanding the system

The SMP has met the objective to better understand the drainage system by conducting and providing the results of a range of hydrological and hydraulic analyses. The analysis has shown that the formal drainage infrastructure is of sufficient capacity. The informal drainage infrastructure (which forms the majority of the drainage network) has varying capacities. A significant proportion of the roadside swales were found to be of low capacity. The potential for flooding damage as a result of the low capacity roadside network was quantified. In at least three streets in the study area there is potential for stormwater flows to enter private property and therefore to potentially inundate buildings.

The performance of the current stormwater management system under the ultimate development scenario was also assessed. Whilst there was an increase in runoff, particularly during higher return period storms the change in the reliability of the system was small. The potential for flooding of private property would however be exacerbated by additional flows through roadside swales which currently have low capacity.

Deficiencies in the existing stormwater management system that could not be modelled hydraulically were also identified. These issues included the management of an overland flow path through private land, the location of localized sag areas within the road network and the nuisance caused by ponding and damage to roadside swales at driveway crossovers. The management of rural runoff originating from the south eastern side of the township was also considered.

Develop strategies to alleviate existing problems

A range of mitigation strategies are recommended. These strategies include:

- Providing formalized driveway crossovers.
- Undertaking assessments of localized sag issues to determine the site specific requirements;
- Purchasing an easement at the corner of Ann Street and George Street to enable better management of overland flows during large rainfall events;
- Undertaking additional assessments of road side swales of specific concern to determine site specific options for increasing capacity;
- Enforcing a minimum finished floor level for new buildings above natural surface levels;

- Requiring new developments to require detention of stormwater such that predevelopment flow rates are maintained for storms up to and including the 1 in 100 ARI event;
- Providing options for management of stormwater within the area between Ashwell Road and Pratt Road which is zoned as Rural Living. This discussion also addressed the need for management of rural flows entering this area; and
- Providing a flow path on the eastern side of the flood levee to manage flows from the Ashwell Road detention basin and runoff generated on Ashwell Road itself to prevent nuisance on private land.

Identify potential opportunities for reuse of stormwater

The community desire to 'green' Wasleys and provide irrigation water for the town oval was strongly expressed during the community consultation. A previous study has found that Managed Aquifer Recharge (MAR) is not likely to be viable in Wasleys. As such, the stormwater harvesting concept developed considered surface water storages only.

Two methodologies were investigated for stormwater reuse in Wasleys. The first involved harvesting stormwater from the residential catchment and utilising the existing Ridley Mill development retention basin, the already proposed Oval Basin and providing an additional harvesting basin along the old Templers Creek alignment. The results indicate that a reasonable security of supply could be provided from such a harvesting system to supply the Oval, School, Bowling Green and John Wasley reserve with irrigation water.

There is also potential for minor stormwater reuse through watering of new or replacement street trees in Annie Terrace and the development of additional plant beds along the main street. The potential for street tree and planting watering is limited due to the generally limited space between the footpath and the kerb and the levels of the existing plantings.

The use of rainwater tanks by the community for non potable use was highlighted as a practical method of reducing the township's reliance on water from the River Murray. Council's existing commitment to the use of Rainwater Tanks for non potable reuse as demonstrated in the current development plan was noted.

Assess the flood risk from Templers Creek

The community expressed concern about potential flooding of new developments by flows from Templers Creek and the capacity of the existing levee. A one dimensional floodplain model was constructed and the estimated flood extent of the 100 ARI event was mapped. The analysis found that the existing levee and Ashwell Road to the south are expected to be overtopped during a 100 ARI event. Similar results were found for a 50 ARI event. During a 20 ARI event the existing levee is expected to provide protection to the town. Ashwell Road is also not expected to be overtopped in a 20 year event.

To provide protection from the 100 ARI flood event the existing embankment/levee would need to be raised approximately 200mm plus freeboard (500mm in total). The modifications to the levee have the potential to be incorporated with the mitigation strategy for managing the outflows from the Ashwell Road detention basin and any works completed to direct rural runoff around any development between Ashwell Road and Pratt Road.

Summary of Recommended Mitigation Strategies and Further Investigations

Wasleys is a small rural township where expensive capital works programs will be difficult to fund. As such the mitigation measures suggested have focused on identifying effective low cost approaches that a have a greater possibility of being implemented.

The following table summarises the recommended works and further investigations. Detailed discussion of the options considered in addition to those finally selected is also presented[1]. The table details the estimated capital and recurrent costs and the recommended timing for implementation of the recommendations. The recommended timeframes for implementation were derived from consultation with Council. These timeframes indicate the relative priority of each of the recommendations. The recommendations have been presented in priority order.

The table also presents the benefits of completing the recommended works or further investigations. At the bottom of the table the criteria used to score against these benefits are described.

Whilst the timing of each of the recommendations has been indicated separately, there is potential for cost savings to be gained from combining the implementation of some of the recommendations. The practicality of whether these cost savings can be realised is dependent on the availability of funding for one or more of the projects and the relative benefit to the community of implementing both recommendations.

Details of how the cost estimates for the mitigation options involving capital works were derived[2] and a summary of the recommended works and further investigations with selected mitigation options broken into sub projects[3] presented in the appendices. These subprojects reflect the way in which Council is likely to implement some of the works.

The potential funding sources for completing the works are also briefly discussed; including Council's infrastructure investment program through which many of the works proposed are likely to be funded

[1] Further discussion of mitigation options in sections 6 and 7.
[2] Costing breakdowns are presented in Appendix D
[3] Recommended works and further investigations broken down by subproject where appropriate are presented in Appendix F.

Project/ Activity Title	Investigation Cost ($)	Capital Cost ($)	Recurrent Cost ($ pa)	Recommended timing (yrs)	Flood Mitigation Benefit				Water Harvesting Benefit			Water Quality Benefit			Other Benefits	
					Score	Measure Used (D) - AAD Reduction (P) - Properties Affected (Q) - Qualitative	Quantification or Description of Benefit	Cost Benefit Ratio	Score	Measure Used (V) - Volumetric (Q) - Qualitative	Quantification or Description of Benefit	Score	Rating (H) - High (M) - Medium (L) - Low	Qualitative Description of Benefit	Rating (H) - High (M) - Medium (L) - Low	Qualitative Description of Benefit
Option 4 Localised sag issues. Inspect individual sites and complete appropriate mitigation	4,000			3	3	P (~13)	Approximately 13 properties immediately adjacent to local sags but the impact would affect general motorists									
Option 5 Nuisance flooding of private land. Consider purchasing and easement from George St	3,000			3	3	P (1)	One property affected, corner of Ann and George Streets									
Option 7 Low capacity roadside swales. Investigate options for increasing swale capacity	6,000			3	4	P (48)	48 properties adjacent to roadside swales with less than or equal to 2 year ARI capacity									
Option 6 Nuisance flooding of private land. Construct swale from detention basin outlet to Goss Road		Cost included in Option 9		7	1	P	Management of urban and rural flows from Ashwell Road development and adjacent rural land away from private agricultural land									

Project/ Activity Title	Investigation Cost ($)	Capital Cost ($)	Recurrent Cost ($ pa)	Recommended timing (yrs)	Flood Mitigation Benefit				Water Harvesting Benefit			Water Quality Benefit			Other Benefits	
					Score	Measure Used (D) - AAD Reduction (P) - Properties Affected (Q) - Qualitative	Quantification or Description of Benefit	Cost Benefit Ratio	Score	Measure Used (V) - Volumetric (Q) - Qualitative	Quantification or Description of Benefit	Score	Rating (H) - High (M) - Medium (L) - Low	Qualitative Description of Benefit	Rating (H) - High (M) - Medium (L) - Low	Qualitative Description of Benefit
Option 9 Regional Flooding. Raise flood levee and form swale	20,000	350,000	7000	7	5	P (township)	The entire township may be affected by floodwaters if the levee fails. A small number of private land parcels will realise benefits from better stormwater management									
Option 11 Increase in runoff from new development. Cut off levee and swale	10,000	109,000	2,500	7	3	P (18)	Provide flood protection for new rural living development (18 properties) and existing residences									
Option 3 Driveway crossovers and water ponding in swales. Provide cement treated driveway cross overs		116,000	5,500	10	5	P (108)	Properties provided with driveway crossovers									
Other greening options. Additional Planted Beds		15,000	1,000	10											M	Greening of main street will provide aesthetic benefits

Project/ Activity Title	Investigation Cost ($)	Capital Cost ($)	Recurrent Cost ($ pa)	Recommended timing (yrs)	Flood Mitigation Benefit				Water Harvesting Benefit			Water Quality Benefit			Other Benefits	
					Score	Measure Used: (D) - AAD Reduction (P) - Properties Affected (Q) - Qualitative	Quantification or Description of Benefit	Cost Benefit Ratio	Score	Measure Used: (V) - Volumetric (Q) - Qualitative	Quantification or Description of Benefit	Score	Rating: H) - High (M) - Medium (L) - Low	Qualitative Description of Benefit	Rating: (H) - High (M) - Medium (L) - Low	Qualitative Description of Benefit
Stormwater reuse and harvesting strategies Water Reuse System		620,000	5,000	10					2	V	Harvesting demand for local green spaces 7.7 ML/a				M	Strong Community support for provision of irrigation water for oval

Flood Mitigation Scoring System			
Score	Reduction in average annual flood damage (AAD) $	Number of Properties Affected	Score
5	> $100k	>50	5
4	$50k - $100k	25 - 50	4
3	$20k - $50k	10 - 25	3
2	$10k - $20k	5 - 10	2
1	< $10k	<5	1

Water Harvesting Scoring System		
Volume of Stormwater Harvested (ML)	Benefit of Re-use	Cost Benefit Ratio
>100	High level of use for existing Reserves & Community Land, future Reserves and Residences	>1
50 - 100	High level of use for existing Reserves & Community Land, future Reserves	0.75 - 1
25 - 50	Meets demands for existing Reserves and Community Land, but not future areas	0.5 - 0.75
5 - 25	Meets demands for localised area only	0.25 - 0.5
<5	Does not fully meet demands for localised area but has other beneficial result	0 - 0.25

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1 Introduction

1.1 Background

Stormwater management plans are a way of helping councils and other catchment managers to recognise the impacts of activities within their boundaries and to develop best practice management strategies and programs. The Stormwater Management Plan (SMP) is used to incorporate good stormwater management into the plans, strategies, policies and actions of local catchment managers.

Australian Water Environments (AWE) was engaged by the Light Regional Council (Council) to develop a Stormwater Management Plan (SMP) for Wasleys.

The main scope of the Wasleys Stormwater Management Plan study was to:

- Build a better understanding of the current drainage regime of the township;
- Develop strategies to alleviate existing drainage problems;
- Identify potential opportunities for reuse of stormwater; and
- Assess the flood risk from Templers Creek.

Council was successful in gaining the support and financial contributions for preparing the Plan from the Adelaide and Mount Lofty Natural Resources Management Board (AML NRMB) and the Stormwater Management Authority (SMA), for the amounts of $20,000 and $10,000 respectively.

An initial community consultation process was used to identify the community vision and objectives for stormwater management in Wasleys. It was through this consultation process that the community and Council identified the highest priorities for stormwater management in the town.

1.2 Legislative Context

The Local Government (Stormwater Management) Amendment Act 2007 came into operation on 1 July 2007. This established the Stormwater Management Authority (SMA) and new financing and governance arrangements for stormwater management and flood mitigation throughout South Australia.

The Authority implements the Stormwater Management Agreement and operates as the planning, prioritising and funding body in accordance with the Agreement. The Stormwater Authority is charged with:

- Working with Councils to facilitate and coordinate catchment stormwater management planning;
- Allocation of State funding to projects in coordination with Council and other sources of financing; and
- Facilitating cooperative action by all relevant public authorities in the planning, construction and maintenance of stormwater management works.

The framework established by the Stormwater Management Act requires Councils to prepare stormwater management plans on a catchment basis, and to implement infrastructure works in accordance with the catchment plans.

The process and content by which Stormwater Management Plans are developed have been formalised by the State Government via the Stormwater Management Authority in a guideline entitled *Stormwater Management Planning Guidelines*.

South Australia's legislative framework provides a number of other legislative tools and policy tools to address water management ranging from state-wide legislation to regional and local policy.

One of the key mechanisms for achieving the desired outcomes of integrated water management is to ensure that the objectives of the Stormwater Management Plan meet and contribute to other State and National Natural Resource Management policies and strategies. These strategies in turn assist in the implementation of the desired water management outcomes in Wasleys.

2 Description of the Study Area

2.1 Study Area

The boundary of the study area was defined by the extent of development within the current Wasleys township and identified by the residential and rural living zones within the Development Plan as consolidated 29 April 2010. The study area and location of the Templers Creek main channel is shown in Figure 1. It includes the area of Ashwell Road in the east to the intersection of Lines Road and Wasleys Road in the west, from the southern end of Pratt Road in the south to the northern most extent of residential development on Goss Road to the north. The study also considered the flood plain of Templers Creek to the east of Ashwell Road and Goss Roads and the rural catchments contributing to stormwater flows in Wasleys from the south.

The general fall of the land in the study area is from southeast to northwest. The study area is bounded by a levee on the eastern side of Goss Road and for a short extent of Ashwell Road and within Council owned land immediately to the South. The levee was constructed to prevent flooding of the town from flows from Templers Creek. Further to the southeast Ashwell Road is also raised above the land to the west.

The current stormwater management infrastructure in the town directs flows originating from catchments to the east of the rail line into the Old Templers Creek channel. Catchments originating to the west of the rail line are directed towards Lines Road, on which there are currently two small dams on private land which collect this water and in wet years overflow onto the road.

2.2 Informal Drainage Infrastructure

The existing stormwater management infrastructure in Wasleys is primarily a road side swale network. The majority of the road side swales are informal unsealed and typically follow the shallow natural fall/grade of the land.

There are sections of kerbing present within the township. The kerbing consists mostly of barrier kerbs with some mountable kerbing on Pratt Terrace. For the purposes of hydraulic modelling the road side drainage with kerbs has been modelled and assessed the same way as earthern road side swales as discussed in section 4.4.3. For this reason kerbed sections of road side drainage have been considered as informal drainage infrastructure in the report. Kerbing does however provide an important drainage service.

Kerbing is limited to the following areas:

- The majority of Annie Terrace;
- The northern end of Station Street;
- The southern section of Goss Road;
- Fisher Street;
- Oldham Street;
- Dunn Court;
- The southern end of Forster Street; and
- A small section of Pratt Road

As indicated in Figure 5 and Figure 6.

2.3 Formal Drainage Infrastructure

2.3.1 Pipe and Side Entry Pit Network

The pipe network in the study area is illustrated in Figure 5. The other nodes that form the existing formal management system include side entry pits (pits), a retention basin, a detention basin and headwalls. The existing nodes in the system are illustrated in Figure 6.

There is a small pipe network starting at the intersection of Annie Terrace and Ann Street which discharges to the Old Templers Creek alignment on private land at the corner of Ann Street and George Street. There is also a network in construction phase within the Ridley Mill development (off Station Street). Stage 1a of the Ridley Mill development is currently under construction. Stage 1 of the development was assumed to be complete as part of the 'current' development extent scenarios modelled.

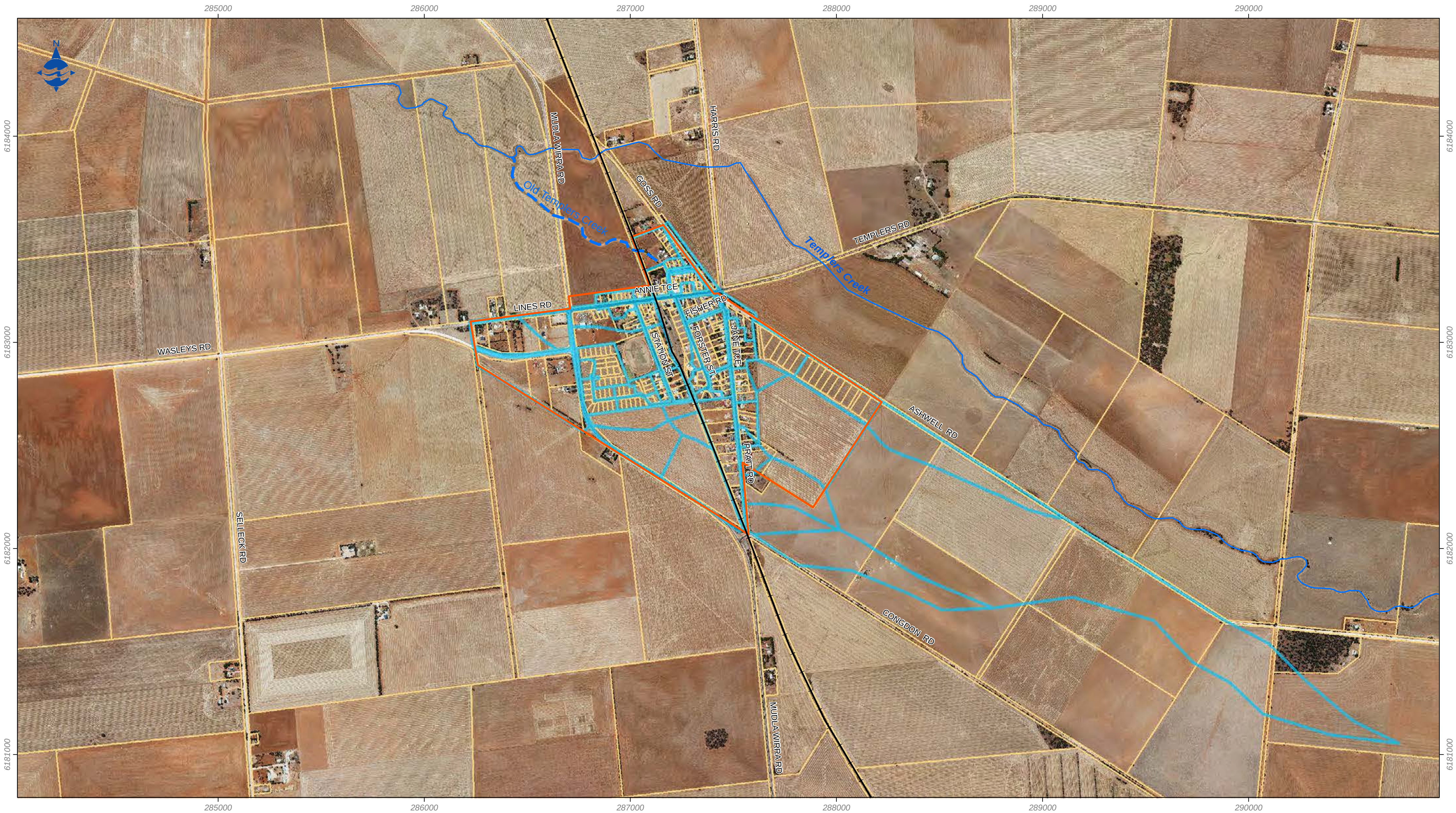
There is also formal infrastructure at the following locations:

- Four culverts (a set of three on the southern side and one on the northern side) under Mudla Wirra Road to convey flows from Annie Terrace to Lines Road;
- A low level outlet pipe under Ashwell Road to convey flows from the detention basin;
- A culvert to convey flows from Jane Terrace to Goss Road under Annie Terrace on the western side of flood levee; and
- A culvert to convey flows under the southern end of Pratt Road.

2.3.2 Basins

There are two formal stormwater basins within the stormwater management system in Wasleys. One is situated within the Ridley Mill development and the other is situated on Ashwell Road as part of the recent Ashwell Road Rural Living subdivision.

There are also three other basins which receive stormwater flows. One is located on eastern side of Pratt Road and two located along Lines Road, on the northern side and the other on the southern side.



LEGEND

- Railway Line
- Templers Creek
- Old Templers Creek Alignment
- Ultimate Development Extent and Study Area
- Extent of Stormwater Contributing Catchments
- Cadastre

Australian WATER Environments

Wasleys Stormwater Management Plan

Location Plan

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Figure 1

2.4 Climate

The annual average rainfall for Wasleys is 498mm. Figure 2 illustrates the annual rainfall volume as measured at the Bureau of Meteorology (BOM) station in Freeling (station number 23325). Figure 3 illustrates the annual average distribution of rainfall. Figure 4 illustrates the distribution of average evaporation throughout the year. The annual average pan evaporation as measured at Roseworthy (station number 023020) is 1763mm/a.

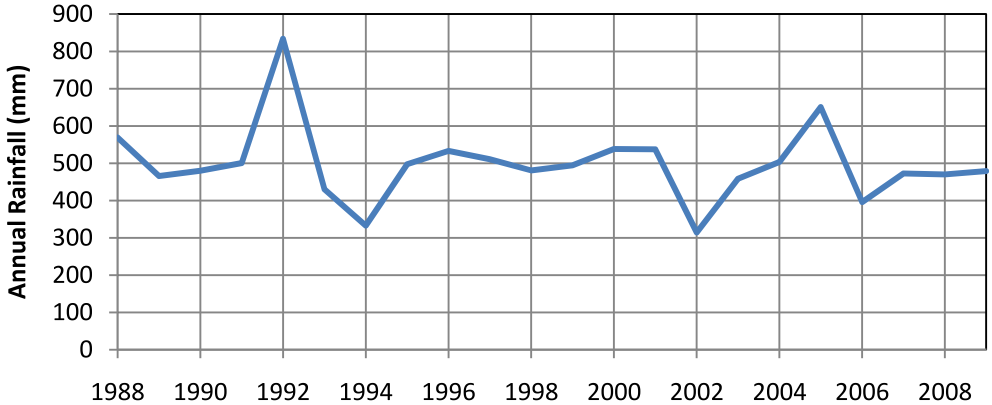

FIGURE 2 ANNUAL RAINFALL DURING LAST 22 YEARS

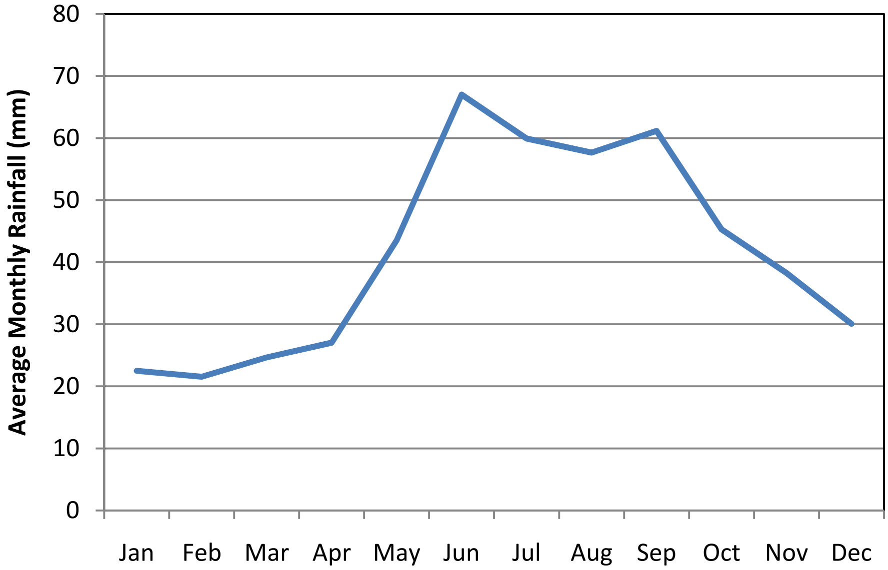

FIGURE 3 ANNUAL RAINFALL DISTRIBUTION

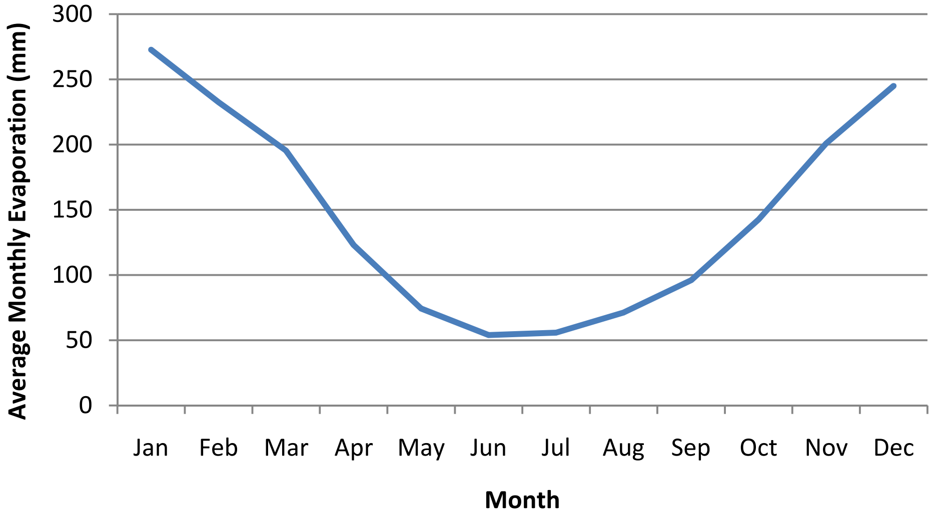

FIGURE 4 MONTHLY EVAPORATION

2.5 Geotechnical Conditions

The soils in the area are generally loam over poorly structured clay (DWLBC Soil and Landscape Attribute Descriptions). The soils generally have moderate to poor infiltration rates which may cause pooling of local runoff for extended periods of time. The Managed Aquifer Recharge (MAR) potential in the area is discussed in section 7.1.

2.6 Potential for Urban Growth

In general, the region to the north of metropolitan Adelaide is experiencing significant urban growth. It is likely that Wasleys in time will undergo increased development pressure. There have been two recent subdivisions within the township and indications that other parcels within the Rural Living zone may be subject to applications for more subdivision in the near future.

For the purposes of this report the potential for urban growth in Wasleys was defined as the extent of the current Rural Living planning zone. Figure 1 illustrates the ultimate development boundary adopted for the analysis.

3 Stormwater Management Objectives

3.1 Consultation

The stormwater management objectives for Wasleys were determined through initial consultation with Council staff, elected members and the community. The community consultation outcomes are summarized in Appendix B. The consultation process included the following:

- A meeting with community group representatives (18th February 2010 at the Wasleys Institute);
- A meeting with long term residents known to have knowledge of historic flooding issues (18th February 2010 at the Wasleys Institute);
- Preparation and distribution of a community survey;
- Review of feedback from the completed community surveys; and
- Preparation and distribution of a letter to interested residents and community groups summarising the findings of the Stormwater Management Plan.

The project has also been overseen by a steering committee including representatives from Light Regional Council, the Adelaide and Mount Lofty Ranges Natural Resources Management Board (AMLR NRMB) and the Stormwater Management Authority (SMA).

3.1.1 General Issues Raised

The following key stormwater management issues were raised through the consultation process:

- Local/ Access streets have areas with water ponded for extended periods after rainfall events;
- There are obstructions in road side swales which exacerbate flooding;
- There is persistent pooling of water in some streets during winter months, this has become worse over time;
- Some sections of the township do not have any formalized drainage infrastructure;
- A desire to prevent property damage due to flooding;
- A desire to ensure new housing developments have appropriate finished floor levels to safeguard against flooding from Templers Creek;
- A desire to ensure flood control embankments are maintained adequately and to appropriate performance standards; and
- A desire to reuse stormwater to irrigate public/community areas in Wasleys.

3.2 Objectives

Through the above consultation process and technical assessments the following stormwater management objectives have been developed for Wasleys. The objectives include:

- To reduce the impact of nuisance local flooding, such as pooling water along streets;

- To provide an acceptable level of protection of assets from local and regional flooding (Templers Creek);
- To manage stormwater to benefit the community through greening of public open space;
- To minimise adverse impacts on downstream environments resulting from stormwater management and water harvesting activities;
- To use the planning system to achieve desirable outcomes for new developments, open spaces, recreation and local amenity;
- To assess stormwater management options and rank their priority in accordance with the format recognized in the SMA/ NRM SMP guidelines with verification against Council wide assessment criteria; and
- To manage rural catchment contributions such that the management, control and harvesting of both rural and urban runoff is efficient and effective.

A brief description of these objectives follows.

3.2.1 Local Flooding

The road network provides the majority of drainage service in Wasleys. The drainage design criteria adopted for this SMP are intended to cater for all design storms, up to and including a 1 in 100 ARI event.

The following criteria were adopted:

All roads are required to be trafficable

The road was assumed to be trafficable when small conventional vehicles can safely traverse the sections of deepest flowing water. The deepest water is expected to occur in the road side swales. A small vehicle is expected to be able to safely traverse flows that are less than or equal to 0.3m deep.

The velocity of the flowing water is also important in determining whether the flow can be safely traversed. The combination of depth and velocity (i.e DxV) reflects the hazard of the flows. To provide safe access for small conventional vehicles the hazard must be low (SCARM, 2000). Low hazard has previously been defined for floodplain mapping projects in South Australia as flows with a depth less than 0.3m and a velocity less than 0.3m/s i.e. a maximum DxV of 0.09 m^2/s. This value of the DxV relationship is also supported by the data in SCARM (2000) which specifies low hazard flows to have a DxV value of less than or equal to $0.09m^2/s$.

Stormwater flows should be contained in the road reserve

Stormwater flows should not inundate and cause damage to areas outside of the road easement. If significant flows leave the road reserve there is potential for damage to private property.

Formal infrastructure to remain effective

Formal infrastructure i.e. pits, culverts and pipes should be functional and not cause nuisance (e.g. through up welling).

Informal infrastructure to remain effective

The informal infrastructure should remain effective with only standard maintenance activities.

3.2.2 Regional Flooding

Flooding of Wasleys from Templers Creek has occurred in the past. Ideally properties within the identified township boundary should be protected from flooding from a 100 yr ARI event. The SMP can assist with achieving this by providing guidance:

- To developers on appropriate finished floor levels to prevent flooding from Templers Creek;
- On the effectiveness of the levee on the eastern side of Wasleys in preventing flooding from Templers Creek within the township; and
- On options for mitigating the recognized flooding from Templers Creek.

3.2.3 Stormwater Reuse

Harvesting of stormwater is desirable to provide water for the greening of Wasleys' public open space. The SMP is intended to describe options for stormwater harvesting within Wasleys and the likely effectiveness of any scheme so that Council can plan for the future development of a reuse scheme should funds become available.

Whilst harvesting of stormwater is to be promoted, any scheme should also have regard to water dependent ecosystems downstream.

3.2.4 Water Quality

Stormwater runoff should not impair the health of downstream environments. The SMP can assist this by estimating the quality of runoff and developing mitigation strategies.

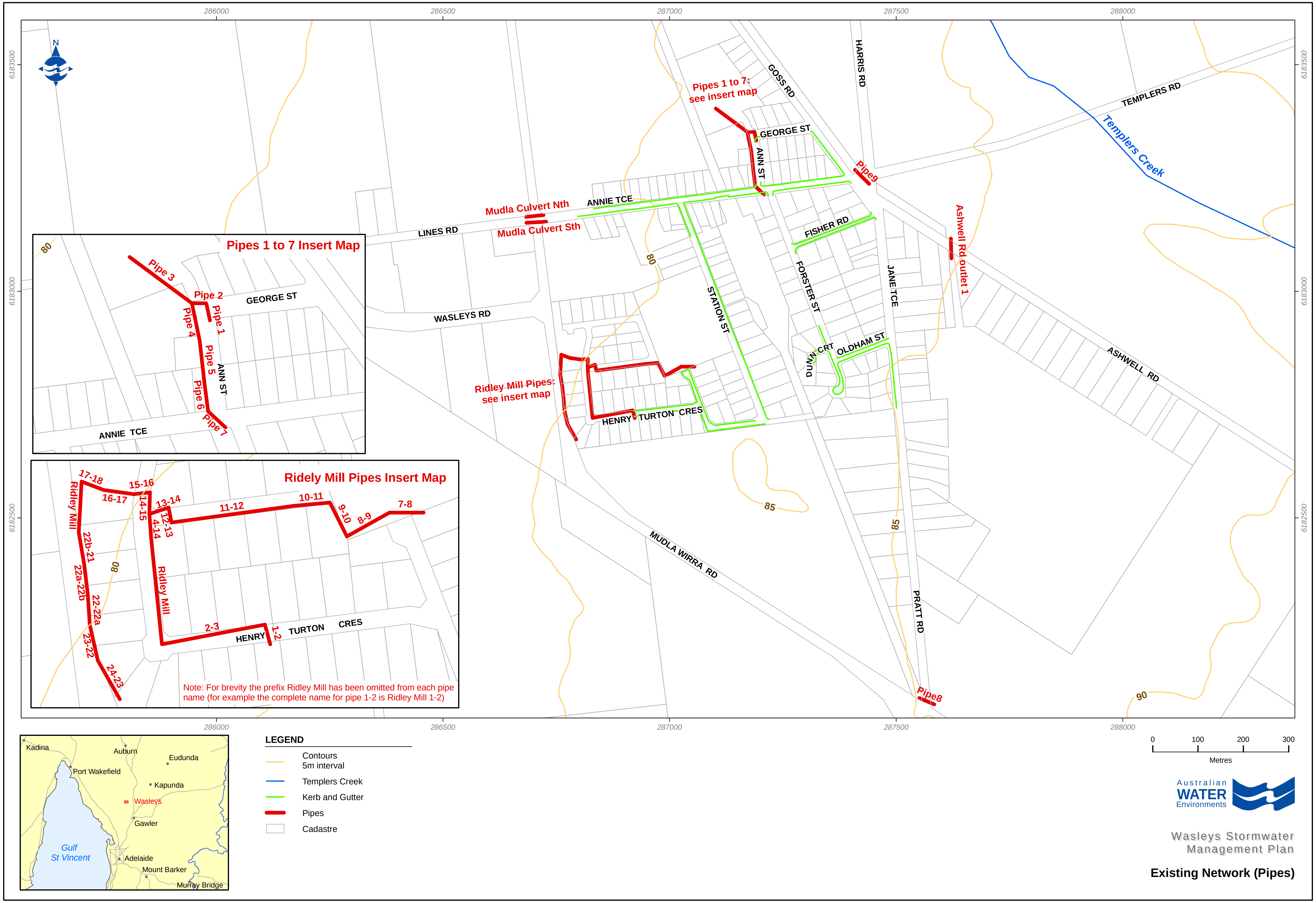

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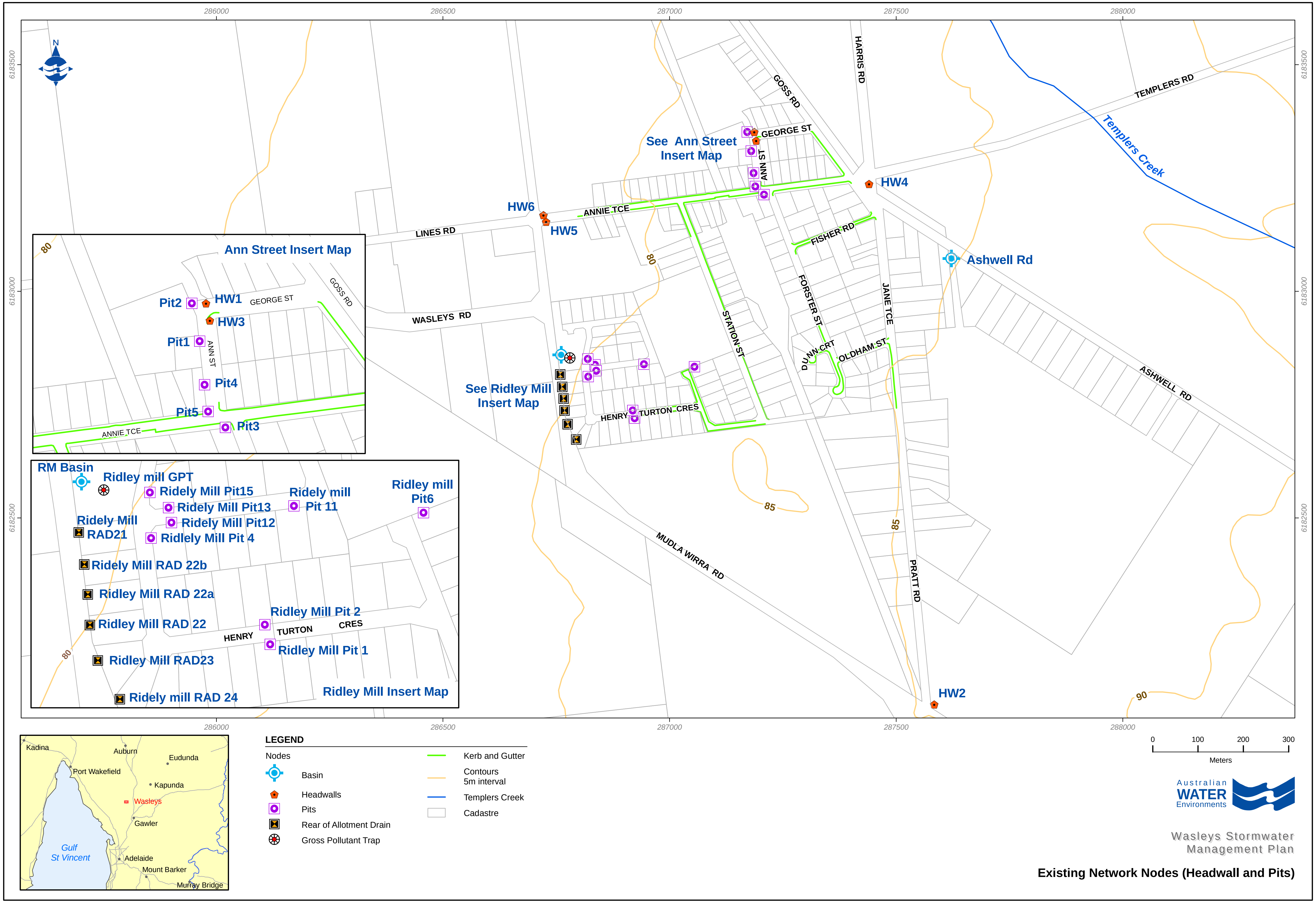
Figure 5



LEGEND

Nodes

- Basin
- Headwalls
- Pits
- Rear of Allotment Drain
- Gross Pollutant Trap

- Kerb and Gutter
- Contours 5m interval
- Templers Creek
- Cadastre

0 100 200 300
Meters

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Wasleys Stormwater Management Plan

Existing Network Nodes (Headwall and Pits)

Job No. 10043 - 011
100525

Figure 6

4 Local Flooding Assessment

4.1 Introduction

Local flooding assessments and identification of drainage system deficiencies were undertaken using three methodologies including, analysis of the anecdotal evidence collated during the consultation, detailed inspection of the road network using the Digital Elevation Model (DEM) created for the township and analysis by the hydraulic modelling. The drainage deficiencies identified using these methods are discussed in detail below.

4.2 Observed Drainage Deficiencies

4.2.1 Introduction

Anecdotal evidence collected during the consultation indicated that persistent water pooling in the road side swales during the winter months is a common problem. The following is a list of roads where this issue has been observed (see Figure 7):

- Goss Road;
- Jane Terrace;
- Forster Street; and
- Pratt Road.

It is has also been noted in the consultation and during a site visit that persistent pooling is often associated with driveway crossovers along the road side swales. The likely cause of problems near driveway crossings is that the driveway crossovers become boggy during winter. Cars then cause ruts in the swale which will increase the depth of the ponded water. Residents are then likely to add material to the swales at the crossovers to make crossing the swale easier and to reduce ponding. The addition of obstructions to the swale will cause more water to pool upstream of the obstruction and make the issue worse.

The general topography in Wasleys is relatively flat. Flows in the road side swales are therefore of reasonably low velocity. The shallow grade of the swales is likely to contribute to persistent ponding after rain events.

The hydraulic modelling technique used for this report cannot be used to consider drainage deficiencies at this scale. However the DEM was used to identify areas of local sag, which has identified some areas where persistent ponding will occur (section 4.2.2).

4.2.2 Localised Sag Issues

An area of localized sag is a depression in the roadway or verge which will not freely drain and will therefore form an area of standing water. Localised areas of sag in the road network which have the potential to cause noticeable ponding and associated nuisance were identified through close inspection of the DEM. Inspection of the DEM for this purpose was restricted to the road reserve.

The areas of sag and their approximate extent and depth are illustrated in Figure 11.

4.2.3 Drainage through Private Land

George Street

The major overflow route and discharge point for the eastern section of the stormwater system is through private land. This is not ideal as large storm events have the potential to cause nuisance drainage on private land.

Under current development catchment conditions for a 10 year storm, water is expected to cross George Street (south to north) from Ann Street but all flows are expected to remain in the pipe under the driveway (pipe 2, east to west) and enter the old Templers Creek channel via pipe 3. However during a 1 in 100 ARI storm the area at the corner of George Street and Ann Street is expected to be awash with water. Flows are expected to cross the driveway entrance and overflows of approximately 0.4 m^3/s are expected to overflow adjacent to the driveway into the Old Templers Creek alignment.

Ashwell Road

The recent rural living development along the western side of Ashwell Road drains to a detention/retention basin on the western side of the road. The outlet of the basin flows under Ashwell Road and discharges in the road reserve on the eastern side of Ashwell Road. Any water flowing from the outlet is expected to flow in a northwesterly direction from the road reserve into private land along the eastern side of the flood protection levee. These flows have the potential to cause nuisance through pooling and water logging and potential damage to crops.

Council has expressed concern that the Ashwell Road detention basin collects runoff from the rural land to the south east along Ashwell Road as well as from the rural living development. Prior to the rural living development on Ashwell Road the flows would have been directed on the western side parallel to Ashwell Road and into the township through the properties on Jane Tce.

The placement of the detention basin in the Ashwell Road development has in effect provided a mechanism to manage the rural runoff from the small catchment (approx. 10 ha) directly adjacent to the western side of Ashwell Road from entering the residential allotments in the township. This detention basin also manages some of the runoff generated along the Ashwell Road itself in addition to the runoff generated on the rural living allotments in the development.

The flows generated on the eastern side of Ashwell Road itself flow into the roadside swale. Rural runoff generated on the eastern side of Ashwell Road appears as if it would be unlikely to enter the road reserve due to the high sides of the road side swale. This runoff is expected to flow parallel to the road reserve toward the corner of Templers Road and the flood levee. The lay of the agricultural land to the east of the road in comparison to the road side swale on Ashwell Road is demonstrated in Figure 11. The symbolization in the figure indicates the side of the swale is elevated above the adjacent agricultural land. The runoff from the eastern side of the roadway is expected to discharge into the private property near the detention basin outlet, as it would have done following the construction of the flood levee.

The installation of the detention basin on Ashwell Road has altered the drainage regime to redirect both rural and the developing urban runoff from the west of Ashwell Road to the east.

Separating the rural and urban runoff contributing to the Ashwell Road detention basin would reduce the volume of runoff entering the detention basin. As the detention basin has a sizable retention component the length of time standing water is present in the basin may be reduced.

Separating the rural flows from the urban flows would require a cut off swale along the southern boundary of the Ashwell Road development to capture the rural flows upstream and direct them toward the western Ashwell Road swale. The diversion of flows from the western side of the Ashwell Road to the eastern side would then be required. The flows would then ultimately flow into the same areas as the current discharge from the Ashwell Road detention basin.

Given the grade of the surrounding land there does not appear to be a gravity driven option to continue to drain the rural runoff through the land on the western side of Ashwell Road. As such, both the current scenario and any alternative to separate rural and urban flows will still direct additional stormwater flows to the private land on the eastern side of Ashwell Road.

Given the limited benefit in redirecting rural runoff from the western side of Ashwell Road as a stand alone project and the fact that the flows would be discharged at the same point, the separation of rural runoff contributions to the Ashwell Road detention basin has not been considered further.

4.3 Hydraulic Modelling

4.3.1 Introduction

Hydraulic modelling of the existing township stormwater network was conducted to better understand the way in which the drainage system functions and its current capacity.

The DRAINS modelling platform (www.watercom.com.au) was used to undertake the hydrological/hydraulic modelling and analysis of the study area. DRAINS is a windows-based program for designing and analysing urban stormwater drainage systems. DRAINS utilises the time-area hydrological method.

DRAINS models consist of nodes and drainage links. The nodes represent infrastructure such as stormwater entry pits, grates and junction boxes. The drainage links represent items such as pipes, channels and overflow paths. Catchments are used to designate the inflow of water into the nodes. Catchment data required by the model includes percentage pervious and impervious area, times of concentration, lag time and total catchment size.

The model was intended to give an indication of drainage deficiencies created by stormwater runoff generated in the catchment. The model does not indicate the extent of drainage problems across the catchment. The results indicate the location of a deficiency along a drainage path and an indicative magnitude of the deficiency. The model was not designed to create a flood map for the township.

4.4 Model Development

4.4.1 Catchment Definition

Stormwater Catchments were defined using topographical data in the Digital Elevation Model (DEM) for the town. Where catchments extended outside of the DEM, 5m contours where used to define the catchments. The DEM and aerial photography were used to gather information on slope, flow path length, the percentage of impervious area and connectivity of catchments.

The catchments within the township were defined to enable modelling of the road side swales in each street. For long streets the catchments were defined to model swale sections of not exceeding 200m in length.

4.4.2 Formal Stormwater Infrastructure

Information on the size and location of the formal stormwater infrastructure was based on the GIS data supplied by Council. The details of the stormwater infrastructure within the Ridley Mill development and the Ashwell Road development were taken from the design and as constructed drawings of the developments supplied by Council. In the case of the Ridley Mill development the design report for the stormwater infrastructure (Tonkin, 2008) was also used.

The data available from Council on the existing stormwater infrastructure did not include invert levels. Approximate invert levels were determined for the infrastructure from measurements conducted on site and comparison with the detail of the DEM.

4.4.3 Informal Stormwater Infrastructure

As discussed in Section 2, the majority of the stormwater infrastructure in Wasleys consists of informal road side swales. To model the capacity of these swales, sections were taken through the DEM using the ArcMap GIS software from the edge of the road reserve to the road centerline. Each side of the road was modelled separately. It was not possible to model the variation in cross section along each road side swale length. For consistency the cross section of the swale at the downstream end was assumed to be representative of its entire length. Road sections with kerbing were treated in the same manner as those with informal swales with the exception of determining time of concentration of catchments where flow times are defined by gutter flow, see Appendix C for details.

To achieve the stormwater management objectives the maximum allowable depth in each swale was set at the maximum depth between the road side swale invert and the road reserve boundary up to a maximum of 0.3m. The maximum DxV (measurement of flood hazard) was also calculated for each swale based on the maximum depth available and a maximum velocity of 0.3 m/s.

There are limitations within the DRAINS model which impact the model's ability to model half road cross sections and the interaction of the each side of the road during large events where water flows over the road crest. As such, it is not possible to model the flow of water across the road when flows in the road side swales reach the level of the road centre line. In these cases it has been assumed that flows cannot cross from one side of the road to the other. As such, the water levels in the road half section in some cases may be artificially elevated and therefore indicated unsafe conditions where in fact these depths had not yet been reached.

The road sections summarized in Table 1 are those where there could be flows across the crown of the road. These results will potentially be affected by limitations of the modelling process and estimated flow depths could be greater than actual. The likelihood of the model results being impacted by this limitation is greater for larger return period storms. The road side swales were labelled based on the street name, the side of the street the swale was located on and the catchment the swale was adjacent to.

TABLE 1 SWALES POTENTIALLY AFFECTED BY LIMITATIONS OF MODELLING FLOW OVER THE ROAD CROWN

Goss Road (24 West) (23 East)	Station St (40 East) (72 west) (43 east) (45 east)
Ann St (25 East) (28 west) (29 West) (29 and 28 west)	George St (30 nrth)
Annie Tce(86 sth) (26 North) (41 sth) (42 sth)	Ashwell Road (9 East)
Forster St (90 west and 22 east) (19 west and 81 East) (17 west)	Jane Tce (12 East)
Oldham St (15 sth) (80nrth)	Old Wasleys Road (68 nrth) (62 sth) (65 sth)
Pratt Road (5 east)(73 west) (3 East)	Ridley Mill Henry Turton Circuit

Key Modelling Assumptions

A number of key modelling assumptions were made that could influence the results. These were as follows:

- The dam along Pratt Road: there is a small dam on Pratt Road for which we do not have details. This dam was modelled as if full and therefore had no impact on the results;
- The two dams on Lines Road were assumed to be full during a design storm event. Again these dams are small and are unlikely to provide significant storage for larger ARI events;
- The Ridley Mill Development Stage 1 dam has been modelled as having 3700m^3 remaining above the standing water level before a storm begins. This is in line with the assumptions in the design report for this development (Tonkin, 2008);
- The Ashwell Road basin acts primarily as a retention basin with only 0.2m of detention depth on top of this retention volume. As such the majority of the basin was assumed to be full during a design event with only the 0.2m of extended detention available; and
- The existing pits within the minor network are of a non standard design. A pit design was selected from the pit database with in the Drains program which had average capture efficiency. Similarly a pit with similar design features to that specified for the Ridley Mill development was selected from the pit database and used in the Drains model.

Additional modelling details are included in Appendix A.

4.4.4 Hydrology

The Average Recurrence Intervals (ARIs) selected for analysis were 2, 5, 10, 20, 50, and 100 years with storm durations ranging between 5 minutes and 1.5 hours. The ARI selected for analysis are consistent with the project brief. The duration of storms assessed was determined by inspecting the results of the hydraulic model. All peak flow conditions throughout the modelled network occurred at times of concentration between 5mins and 1.5 hours.

4.4.5 Ultimate development scenario

The areas described in Council's Development Plan as Rural Living which are not currently developed have been assumed to have 5% directly connected paved area, 5% supplementary area (where supplementary area is defined as paved area which discharges on to impervious areas before entering the drainage network) and 90% grassed area under the ultimate development scenario. The time of concentration of these catchments has been assumed to be equivalent to the approximate flow time expected in a gutter over the longest flow path length in the catchment.

The assumed percentage of impervious area was based on the allotment sizes similar to the Ashwell Road development with impervious areas equivalent to those estimated for the Rural Living allotments along Pratt Road, as measured from aerial photography.

4.5 Hydraulic Modelling Results

The DRAINS model was used to determine the capacity of the existing stormwater infrastructure and the informal road side swale network, based on the criteria discussed in section 3.2.1. This analysis was completed under the current and ultimate development catchment conditions and for design storms of 100, 50, 20, 10, 5 and 2 year ARI.

4.5.1 Formal Drainage Infrastructure

Under all the scenarios tested there was no failure of the pipe and pit network by up welling. Therefore the existing networks were found to operate without causing nuisance.

The two basins within the existing network, the Ashwell Road Detention Basin and the Ridley Mill Retention Basin did not overtop under any of the scenarios tested.

The maximum outflow rate for the Ashwell Road detention basin was found to be 0.219m^3/s in a 100 year event. Initial analysis of the likely velocities at the outlet of the detention basin will be low (0.3-0.5 m/s). The likelihood of scour in large rainfall events is moderate in the area immediately adjacent to the field outlet. This area is partially protected by rock protection. The area surrounding the outlet leading to the private land to the east is of shallow grade. The velocities further away from the outlet will be lower and the potential for scour outside of the road reserve is low. The greatest potential for damage on private land as a result of flows from the detention basin outlet is through water logging and nuisance caused by ponding.

4.5.2 Henry Turton Circuit

Under both current and ultimate development conditions Henry Turton Circuit North was found have a capacity of up to and equal to the 50 yr ARI. This section of kerb and gutter within the new development failed for the 100 yr event by exceeding the VxD relationship criteria. The flow path meets all the other criteria assessed. The performance of this section of kerb and gutter is considered at the upper limit of performance with regard to flood hazard (as expressed as VxD) but is acceptable given the formed nature of the road and the limited width of the flow path. It has therefore been displayed on Figure 7 -Figure 10 as having greater than 100 year capacity.

Henry Turton Circuit South, under both current and ultimate development conditions was found to have a capacity of up to and equal to 20 yr ARI. As with the northern side of this road the kerb and gutter design met all criteria with the exception of the VxD criteria. This section of road is also considered to be performing near the upper limit of performance in a 100 year event but is consider acceptable given the formed nature of the road and the limited width of the flow path. It has therefore been displayed on Figure 7 -Figure 10 as having a greater than 100 year capacity.

4.5.3 Informal Drainage Infrastructure

Drainage Deficiency Rating

The capacity of each of the road side swales was calculated for the current and ultimate development scenario. The results of this analysis, as described by the maximum return period (expressed as ARI) that meets the criteria for each swale, and are illustrated in Figure 7 and Figure 8. For this analysis sections of road with kerbing and those without were treated the same. The drainage capacity reported is the capacity measured at the downstream end of the swale. It is therefore possible that capacity of the swale will vary along its length.

Under ultimate development conditions the ARI rating of three swales was reduced due to the additional runoff, namely:

- Goss Road 35 East;
- Pratt Road 3 and 5 East.

Failure Mechanism

The failure mechanism has been mapped for each road side swale if its capacity is not sufficient to convey a 1 in 100 year storm event. The failure mechanism considers how the swale fails. There were four scenarios considered:

- *Overflows with potential to inundate properties.* Under this scenario the swale was predicted to overflow and analysis of the fall of the properties adjacent to the road indicates that most of the properties fall away from the road. There is therefore a greater opportunity for inundation of assets under this scenario in comparison to the other failure scenarios;
- *Overflows with less potential for inundation*. Under this scenario the swale has been shown to overflow but analysis of the fall of the properties adjacent to the road has found that most of the properties rise away from the road. There is therefore a reduced chance of inundation of private property under this scenario;
- *Fails due to exceeding VxD relationship.* Under this scenario inundation of properties is not anticipated, traversing the flows in the road side swale or gutter will potentially be difficult for small conventional vehicles and may be difficult to cross by foot. As discussed in section 3.2.1 to meet the design goals the hazard of the flood flows should be low (and in this case the hazard rating would be medium or worse); and
- *Flows across road, capacity not assessed.* Flow routes marked with this scenario are locations were flows will overtop the road crown. In areas where flows across the road crown have the potential to be great cross sections have been taken and safe flow criteria have been assigned. At sites where cross sections have not been taken and no safe flow criteria have therefore been assigned the flow across this location is recorded in the results (see Appendix C) but a drainage capacity has not been determined.

The failure mechanism represented in the figures is the worst case scenario. That is, a flow path may initially fail due to exceeding the VxD relationship at a return period less than 100 ARI but during a 100 year event does overtop. The failure mechanism mapped would reflect the worst case scenario result i.e. that the flow path will fail by overtopping.

The results for all modelling runs are summarized in Appendix C. A summary of the results are also presented in Figure 9 and Figure 10.

4.5.4 Limited Roadside Swale Capacity

The results of the hydraulic modelling show that there a number of sites where the road side swale network is of low capacity and that there is potential for stormwater to enter private property. The results also indicated that there a number of sites where the majority of the adjacent properties fall away from the road and there is increased risk of water flowing into buildings.

The swales which have the most potential for flooding private property under current catchment conditions are listed in Table 2. The depth of the flow expected from the swale into the properties is also summarized in this table to indicate the potential magnitude of the issue.

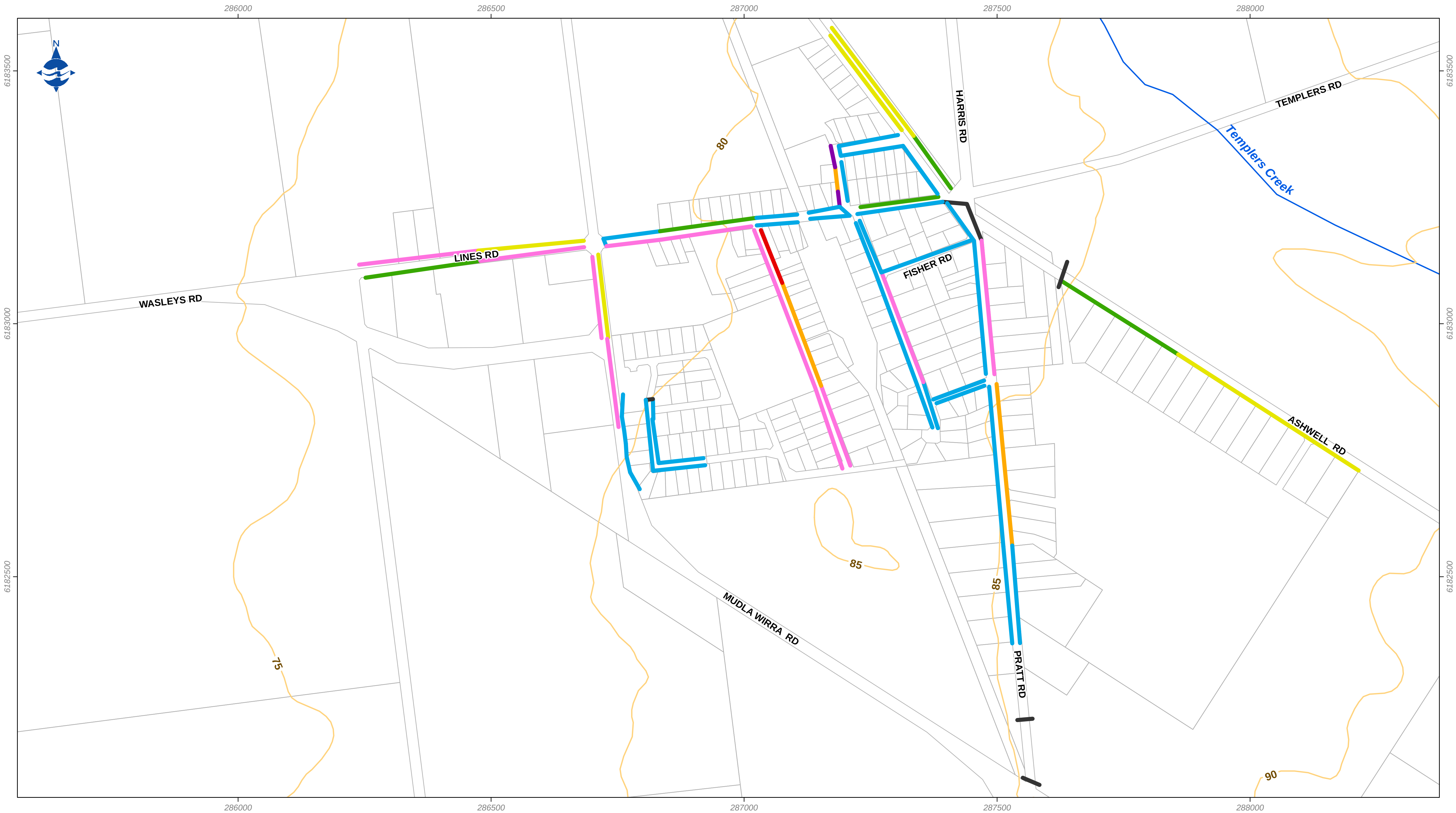
The results of the analysis of the ultimate catchment development condition indicate an increase in frequency of roadside swale capacity being exceeded due to the increased runoff. Under the 1 in 100 ARI storm conditions there is an increase in flow rates in overland flow paths of:

- 70% from the corner of Ann Street and George Street to Old Templers Creek channel;
- 20% along the northern side of Lines Road; and
- 60% along the western side of Goss Road.

In a 1 in 10 year event at the same locations there is an increase in flow rate of between 0 and 20% under ultimate catchment conditions in comparison to the current catchment development.

TABLE 2 SWALES WITH THE GREATEST POTENTIAL FOR FLOODING PRIVATE PROPERTY

Swale	Depth of flow into adjacent properties under current development intensity and a 100 year ARI design storm (mm)
Old Wasleys Road (66 Nrth)	49
Old Wasleys Road (68 Nrth)	73
Mudla Wirra (67 West)	98
Mudla Wirra (70 East)	312
Station St (43 East)	20
Station St (44+45)	93
Station St (71 west)	88



LEGEND

Contours 5m interval	**Overflow Routes**		5
Templers Creek	**Current Capacity (ARI)**		10
Cadastre		Flow across road capacity not assessed	20
		< 2	50
		2	> 100

NOTE:
See report section 4.5.1.1 for discussion
of Henry Turton Circuit results

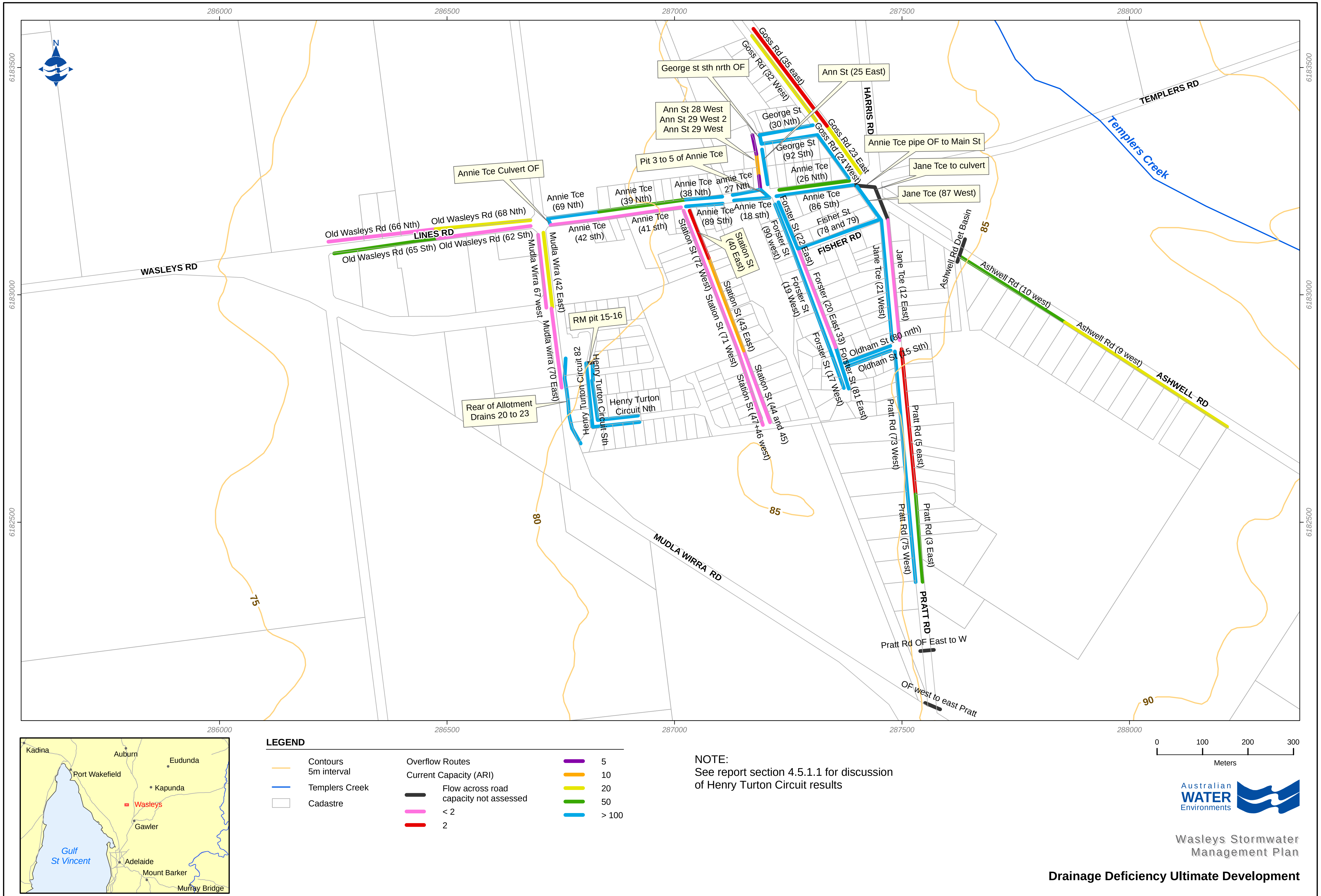
0 100 200 300
Meters

Wasleys Stormwater
Management Plan

Drainage Deficiency Current Development

Job No. 10043 - 012
100826

Figure 7



LEGEND

Contours 5m interval	Overflow Routes		5
Templers Creek	Current Capacity (ARI)		10
Cadastre		Flow across road capacity not assessed	20
		< 2	50
		2	> 100

NOTE:
See report section 4.5.1.1 for discussion of Henry Turton Circuit results

0 100 200 300
Meters

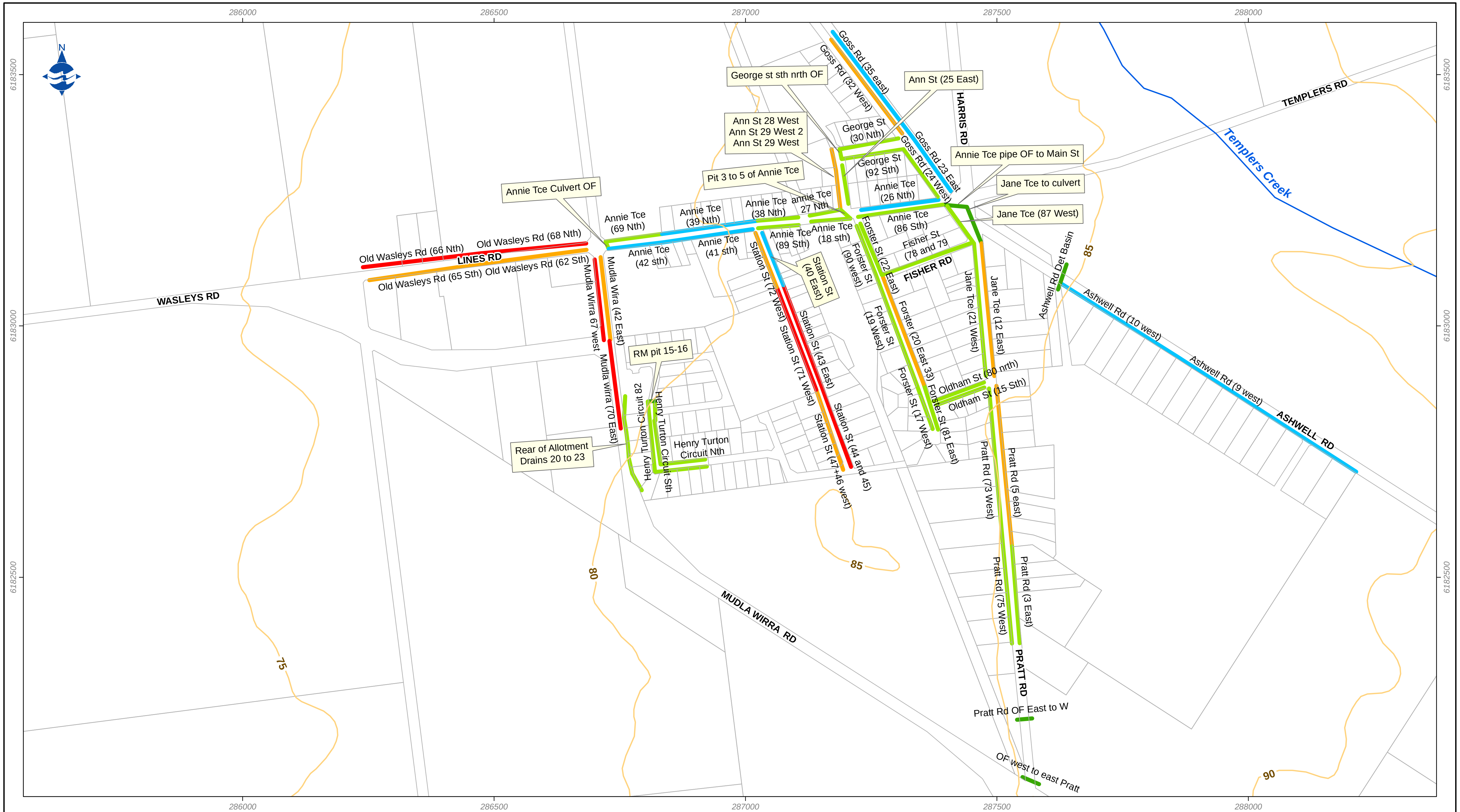
Australian WATER Environments

Wasleys Stormwater Management Plan

Drainage Deficiency Ultimate Development

Job No. 10043 - 013
100826

Figure 8



LEGEND

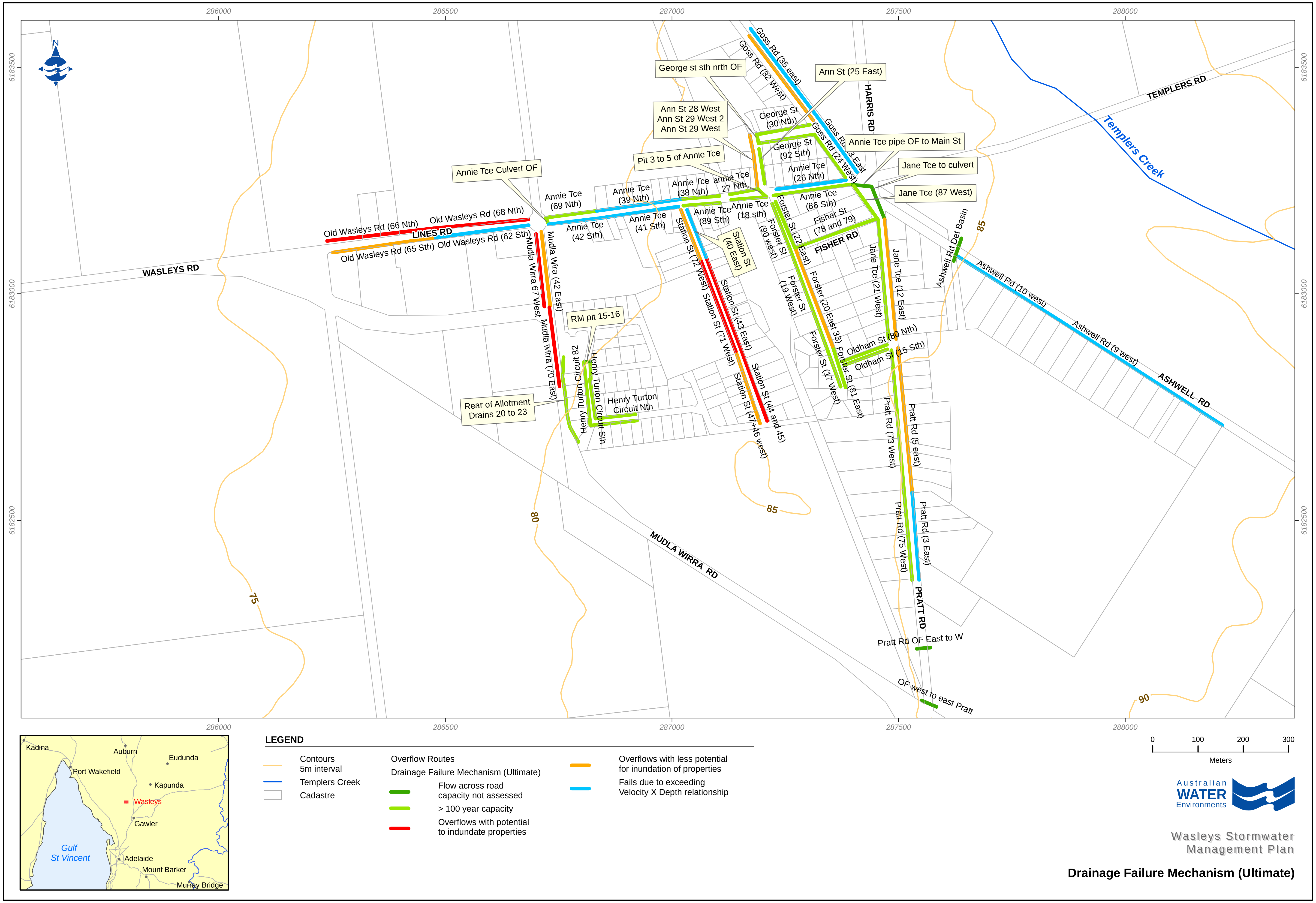
	Contours 5m interval		Overflow Routes		
	Templers Creek		Drainage Failure Mechanism (Current)		Overflows with less potential for inundation of properties
	Cadastre		Flow across road capacity not assessed		Fails due to exceeding Velocity X Depth relationship
			> 100 year capacity		
			Overflows with potential to inundate properties		

0 100 200 300
Meters

Australian WATER Environments

Wasleys Stormwater Management Plan

Drainage Failure Mechanism (Current)

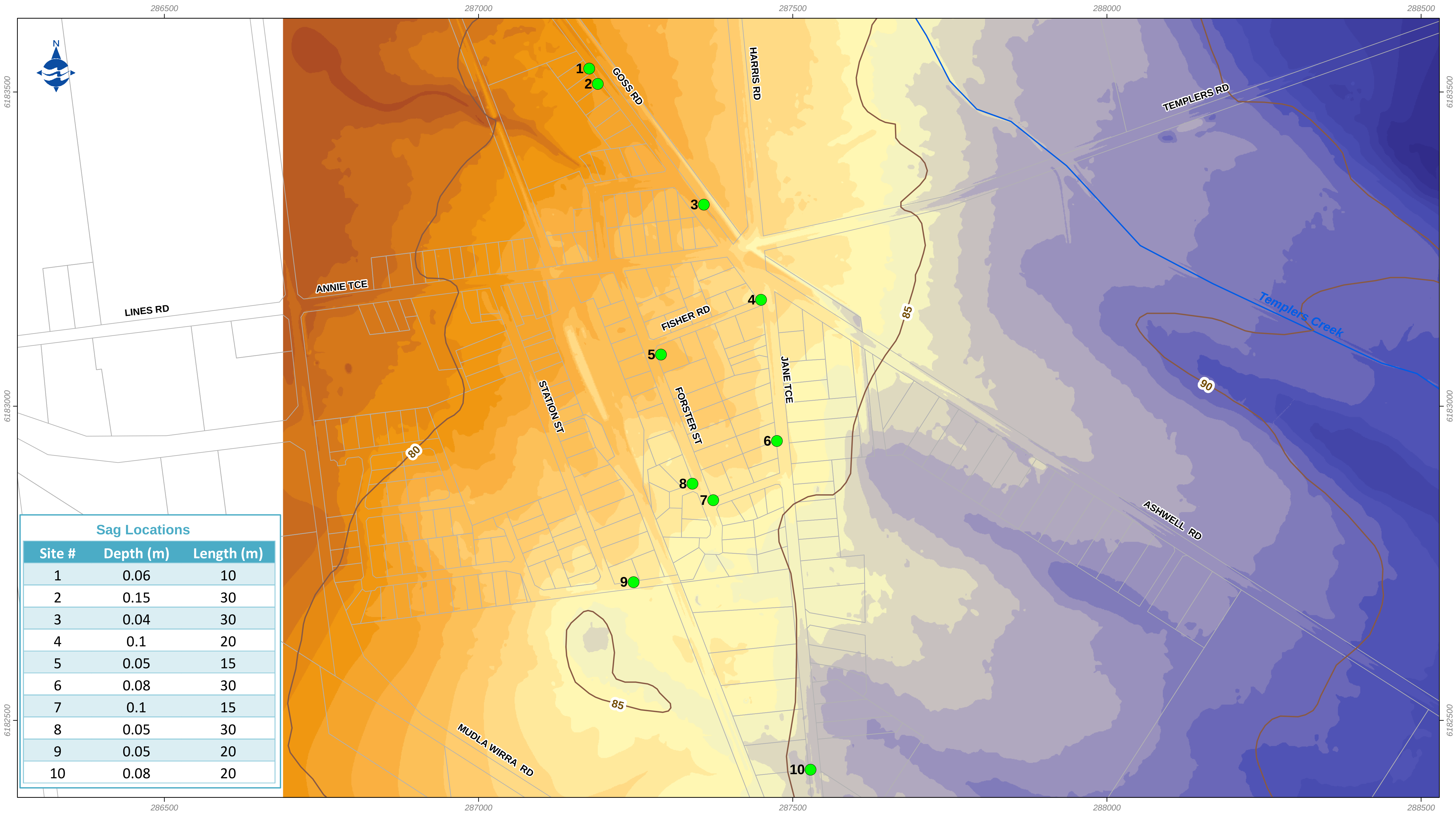


Wasleys Stormwater Management Plan

Drainage Failure Mechanism (Ultimate)

Job No. 10043 - 015
100826

Figure 10



Sag Locations

Site #	Depth (m)	Length (m)
1	0.06	10
2	0.15	30
3	0.04	30
4	0.1	20
5	0.05	15
6	0.08	30
7	0.1	15
8	0.05	30
9	0.05	20
10	0.08	20

LEGEND

- Sag Locations
- Contours 5m interval
- Templers Creek
- Cadastre

Elevation (mAHD)

75.5 - 76	79 - 80	84.5 - 85	92 - 93
76 - 77	80 - 80.5	85 - 85.5	93 - 94
77 - 78	80.5 - 81	85.5 - 86	94 - 95
78 - 79	81 - 81.5	86 - 86.5	95 - 96
	81.5 - 82	86.5 - 87	96 - 97
	82 - 82.5	87 - 88	97 - 98
	82.5 - 83	88 - 89	98 - 99
	83 - 83.5	89 - 90	99 - 100.3
	83.5 - 84	90 - 91	
	84 - 84.5	91 - 92	

0 100 200 300
Meters

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Wasleys Stormwater Management Plan

Localised Sag Issues

5 Regional Flooding Issues

5.1 Background

Templers Creek is located on the eastern side of Wasleys (see Figure 1). It is a natural stream that flows northward, parallel with Ashwell Road before turning westward and flowing over Goss Road and under the railway bridge to the north of the township. The creek flows through private agricultural land. The channel vegetation has been completely modified by these agricultural activities. The creek contributing catchment area is approximately 74 km^2 with the land use predominantly agricultural.

A flood levee has been built on the eastern side of the residential zone for flood mitigation purposes (circa 1919). This levee has been breached in the past (1952 event) but was subsequently repaired and raised. More recent flooding events in the 1960s, 70s, 80s and 90s did not threaten the town.

Nevertheless some residents have expressed concern that newer developments in Wasleys are potentially at risk of flooding from Templers Creek.

The form of the creek changes south of Templers Road. Upstream, flows are contained by ridges rising on both sides of the channel. Closer to Templers Road the ridge on the western side ceases and the land falls away toward Ashwell Road. In this reach the capacity of the creek is significantly lower than the upstream sections. This shallow, poorly defined main channel continues north of Templers Road until the creek passes under the rail line. Downstream of the rail line bridge the creek capacity increases significantly.

A floodplain map for this event was developed to understand the level of protection provided by the existing levee and potential extent of flooding in a 1 in 100 ARI flood event. The following sections detail the development of the model and the results. Figure 12 illustrates the inundation extent of the 100 year event.

5.2 Modelling Process

A 1 dimensional open channel modelling program called HEC RAS was used to model creek and floodplain. A DEM was developed to assist with the floodplain hydraulic modelling. The DEM was based on soft photogrammetry approach and topographical survey data for Ashwell Road. The along. The topographical data extends along Ashwell Road from adjacent to the Ashwell Raod detention basin to the end of the new development. The east- west extent of the survey is from the eastern side of Templers Creek and includes the full width of Ashwell Road. The elevation of the main channel ranges from 100m AHD at the upper reaches of the mapping area to 75m AHD at the lower reaches. The DEM was used to develop the channel geometry for the main channel and the floodplain. Key modelling inputs for the model are described in Table 3.

The 1 in 100 ARI flood event peak flow used in the modelling was based on the hydrological model developed, using a RORB model, for the Light River and Salt Creek/Templers Creek catchments as part of the flood mapping of the Light River currently being conducted (Australian Water Environments, 2010). The hydrology developed as part of the Light River floodplain mapping project has been carefully reviewed by the project steering committee including representatives from the Department of Transport Energy and Infrastructure.

Australian Water Environments (2010) considered summer and winter storms. The study observed that the summer storms had a shorter duration and a higher peak in comparison to winter storms which were of longer duration but had a lower peak. The peak flow assumed for modelling of Templers Creek was therefore based on the summer storm hydrograph shape.

The critical storm duration for floods in Templers Creek at Wasleys is between 6-9 hours for the 20-100 year ARI storms. This is in contrast to the range of times of concentrations of flows in the township as modelled using the Drains model which are between 15 mins to 1.5 hours. Because the time of concentrations are so different it is unlikely that the same rainfall event will generate a significant flow event in Templers Creek and in the township. As such it is not considered necessary to consider the impact of regional flooding on the ability of the town stormwater management network to operate effectively.

As discussed above, the capacity of Templers Creek just upstream of Templers Road is less than the capacity further upstream where it is confined by ridges rising on both sides of the channel. The capacity of this and the reach downstream was assessed and found to be approximately 2.4 m^3/s. This capacity is significantly lower than 100 ARI flow rate. The model was therefore constructed as two channels, the main channel and an overflow channel. Analysis of the DEM indicated that the overflow channel would form along the eastern side of Ashwell Road and the existing levee. Where flow rates in the main channel upstream of Templers Road exceeded 2.4m^3/s the remainder of the flow is modelled in the overflow channel.

The model was not extended west over Ashwell Road, the levee and the rail line in the north. The land to the west of these boundaries falls away to the west. Flows into these areas cannot be modelled using the 1 dimensional techniques used here.

The previous floodplain mapping work completed by Gilbert and Associates (August 2008) was based on a peak flow of 85m^3/s.

TABLE 3 HECRAS KEY PARAMETERS

Variable	Value (m^3/s)	Notes
Flow rate 1:100 ARI	97.1	Peak flow developed by AWE (2010)
Flow rate 1:50 ARI	68.0	Peak flow developed by AWE (2010)
Flow rate 1:20 ARI	36.9	Peak flow developed by AWE (2010)
Mannings "n" (main channel)	0.035	Clean, straight, full, no rifts or deep pools but more stones and weeds (HecRas)
Mannings "n" (left and right bank overbank areas)	0.030	Cultivated areas – no crop (HecRas)

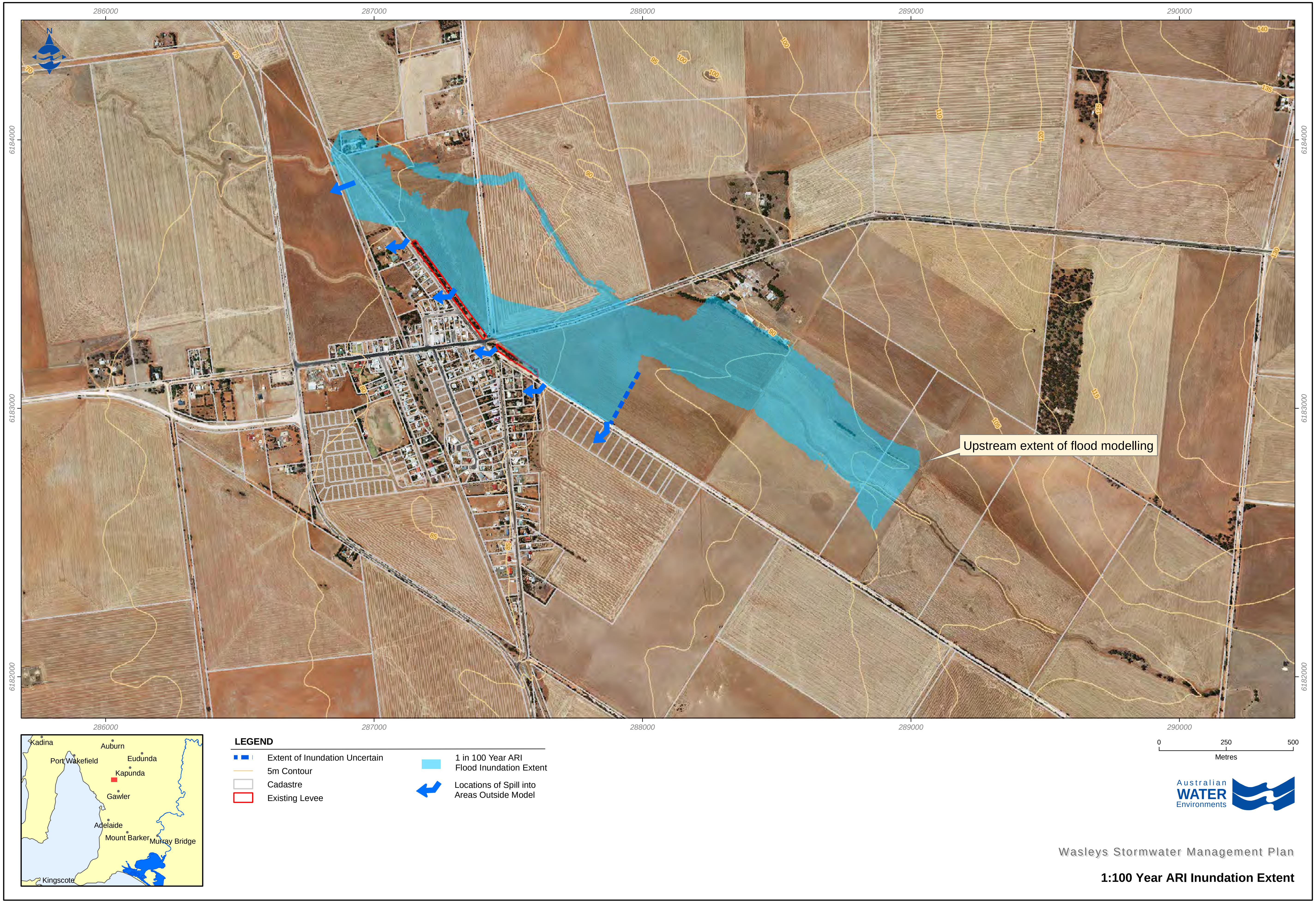
5.3 Modelling Results

The estimate of flood extent in a 1 in 100 ARI event is illustrated in Figure 12. The mapping indicates that a 100 year flood would flow across Ashwell Road, overtop the existing levee and would overflow Goss Road to the north of the existing levee extent and flow over the rail line west ward. The flows over Goss Road to the north of the existing levee extent are not expected to flow into developed areas as the topography in this area falls to the north. Whilst the flow paths for overflows into the township have not been mapped the general fall of the land is from South East to North

West. Flows that overtop Ashwell Road will flow toward Jane Terrace and the centre of the township. Flows overtopping the levee will enter the centre of the township with some directed down the channel of the Old Templers Creek alignment.

Analysis of the 1 in 50 ARI event indicated similar results with Ashwell Road likely to be overtopped to the south and the existing levee to be overtopped in a number of locations. The results of the 1 in 20 ARI event indicated that Ashwell Road is unlikely to be overtopped south of the levee and that the levee would prevent flood flows from entering the township. A 1 in 20 ARI flood would be expected to cross Goss Road north of the existing levee extent but as discussed above these flows would not be expected to flow south toward the town.

Appendix E includes key cross sections from the HEC RAS model demonstrating the water surface elevation for the 50 year ARI event.



Australian WATER Environments

Wasleys Stormwater Management Plan

1:100 Year ARI Inundation Extent

Job No. 10043 - 016
101030

Figure 12

6 Local and Regional Flood Management Strategies

A number of mitigation strategies and further investigations required have been identified to reduce flood risk and address drainage deficiencies. Wasleys is a small rural township where expensive capital works programs will be difficult to fund. As such the mitigation measures suggested have focused on identifying effective low cost approaches that a have a greater chance of being implemented. Section 9 provides a summary of the recommended works and further investigations including: costs, benefits, priorities, timeframes and potential funding for implementing the recommended options.

The following sections present mitigation options for local and regional flood management strategies. Where multiple strategies are presented recommendations are made on the preferred strategy. Where appropriate cost estimates for implementation of the works or further investigations are presented. A detailed breakdown of how these costs were derived is included in Appendix D.

6.1 Issue 1: Driveway Crossovers and Water Ponding in Swales

6.1.1 Mitigation Option 1: Provide kerb and gutter and formal driveway crossings in all residential streets

This mitigation option would provide a lower channel roughness and therefore more efficient flow in the roadside channel. This would also reduce the potential for changes in grade, due to damage to the swale invert, to cause ponding. This option of formalizing road side drainage infrastructure has been included as it was identified by the community during consultation. It is however prohibitively expensive and is not considered to provide significant benefit above cheaper alternative options.

6.1.2 Mitigation Option 2: Provide concrete driveway crossovers

This mitigation option involves providing driveway crossovers along streets which do not currently have kerbing to prevent ruts forming in the roadside swale and to reduce the desire of residents to add obstructions to the swale to provide safe access to their properties. The installation of the driveway crossovers would allow for a more efficient channel cross section and reduce a major cause of stormwater pooling within the street network.

6.1.3 Mitigation Option 3: Provide cement treated driveway crossovers

This mitigation option involves providing driveway crossovers as per Option 2 but uses cement treated road base material or lean mix concrete to line the driveway crossovers. This material will not be as durable as concrete but will provide similar short term benefits. The lean mix concrete is expected to be more durable than the cement treated road base. The lower durability in comparison to concrete will require some maintenance activities but this should be minimal. The cost estimates for construction of the mitigation options for issue 1 are summarized in Table 4. These costs assume that the mitigation strategies would be completed as a series of separate projects on a street by street basis.

TABLE 4 ISSUE 1: MITIGATION OPTION COSTS

Mitigation Option	Capital Cost ($ GST ex.)
1. Kerb and Gutter	1,308,000
2. Concrete Driveway Crossovers	186,000
3. Cement treated sub base driveway crossovers	116,000

6.1.4 Issue 1: Recommended Option

Considering the costs involved the , likely life of the various driveway crossovers and maintenance required it is recommended that Option 3 is the preferred approach to mitigating damage to the road side swale and water pooling.

6.2 Issue 2: Localised Sag Issues

6.2.1 Mitigation Option 4: Inspect individual sites and prepare appropriate design

To prevent nuisance ponding of stormwater in the localized sag locations it is recommended that a site inspection take place and a site specific mitigation measure be developed. At some sites there is kerbing, therefore any remediation is likely to involve changes to the asphalt surface and potentially the associated gutter levels to ensure the site is free draining.

In some cases the sites are located within areas with no kerbing present. The remediation of the road side swales may involve regrading of the swale in the localized area or placing compacted fill within the affected area.

A cost estimate has been provided for the initial site inspection and design costs for providing remediation of the local sags identified. The construction works required are likely to be small scale and possibly within the capabilities of Council's resources to complete on an opportunistic basis when other works are being conducted in the area. Completing works at similar sites at the same time will provide economy of scale and reduce construction costs.

The cost estimate to complete mitigation option 4 is summarized in Table 5.

TABLE 5 ISSUE 2: MITIGATION OPTION COSTS

Mitigation Option	Capital Cost ($ GST ex.)
4. Site inspection and design of site specific remediation	4,000

6.3 Issue 3: Nuisance Flooding of Private Land

6.3.1 Mitigation Option 5: Creating an easement for the flow path to Old Templers Creek

The most effective way to manage flows from the eastern side of the Wasleys township is to continue to direct water to the Old Templers Creek channel. Creating an easement from the George Street and Ann Street corner through to the formalized channel of Old Templers Creek would provide Council with the opportunity to formalize access arrangements to manage overflows away from the private driveway. Managing flows away from the driveway will help maintain safe access to the property.

For costing purposes a nominal value has been included in the summary table in Appendix F to cover the cost of Council time to complete the necessary processes.

The recommended location of the easement is illustrated in Figure 13.

6.3.2 Mitigation Option 6: Construct swale from Ashwell Road detention basin outlet on eastern side of flood levee

The fall of the land downstream of the Ashwell Road detention basin outlet is to the northwest along the eastern side of the existing flood levee. The works recommended preventing nuisance and damage caused by ponding of stormwater on private land include:

- Creating a channel of sufficient capacity to convey flows from the detention basin outflows and the contribution from the road runoff on the western side of Ashwell Road. This channel would need to include an outlet through the extended flood levee discussed in Issue 5. This would require a non- return valve to prevent flood water flowing under the levee at this point during large Templers Creek flood events;
- This channel would convey flows from the discharge point in the road reserve on Ashwell Road through to the point on Goss Road where the main channel crosses. The design of this swale should be integrated with any upgrades to the flood levee. The exact design of the swale would need to be confirmed during detailed design however the width of land required for the swale would need to be in the order of 8m wide including the land needed to form the eastern side of the swale. It may be necessary to purchase land in addition to the existing Council land to allow for the swale proposed;
- The capacity of the existing culvert under Templers Road will need to be assessed as part of the design; and
- A point at which flows cross Goss Road in the north into the main Templers Creek channel will also need to be designed.

For costing purposes it has been assumed that these works would be completed as part of addressing the works recommended to manage regional flooding (i.e. raising the levee).

Section 4.2.3 suggests that completing works to separate the rural runoff from the catchment contributing to the Ashwell Road basin would not provide significant benefit as a stand alone project. If the works discussed in 6.6.2 (mitigation option 11) are implemented they will effectively remove the rural catchment from contributing to the Ashwell Road basin and transfer the rural runoff to the eastern side of Ashwell Road.

The proposed alignment of the levee is illustrated in Figure 13.

6.4 Issue 4: Low Capacity Road Side Swales

6.4.1 Mitigation Option 7: Investigate options for increasing existing swale capacity in problem areas.

Further investigation of the site specific mitigation strategies to increase swale capacity is necessary. This would include a further analysis of the DEM and a site inspection to confirm the extent of the low capacity areas within the swale and to determine if there is potential for one of the following techniques to be applied:

- Raise road verge - this option needs to be tested to ensure it will not result in forcing the flooding across the road verge and exacerbate problems on the opposite side of the road;
- Deepen the swale invert - this option needs to be tested to ensure it is possible within the constraint of the downstream network levels.

The cost estimate for completing mitigation option 6 is summarized in Table 6.

TABLE 6 ISSUE4: MITIGATION OPTIONS COSTS

Mitigation Option	Capital Cost ($ GST ex.)
6. Investigate options for increasing existing swale capacity in problem areas	6,000

6.4.2 Mitigation Option 8: Enforce a minimum raised floor level above natural surface

Raising new building floor levels above the surrounding levels will provide protection from local stormwater flooding issues and will also assist with preventing floodwater from Templers Creek entering homes.

Due to the relatively flat topography of the Wasleys township it is possible for floodwaters from Templers Creek which overtop the levee, during a rare (severe) storm, to spread widely within the township. Even with a raised levee the risk of levee failure during a lower return period storm must still be taken into account. Providing a minimum raised floor level will also provide some measure of protection against floods larger than the 100 year ARI event occurring .

It is also difficult to predict where flows from either regional flooding or as a result of overtopping of roadside swales will spread in a relatively flat residential area. This is due to the obstructions caused by residential structures, fences and minor diversions.

It is therefore recommended that council require all new development floor levels to be set 300mm above natural surface levels. Flood damage costs increase significantly when flood waters enter a building.

6.5 Issue 5: Regional Flooding

6.5.1 Mitigation Option 9: Raise Levee

If the flood protection provided by the existing road network and levee is not considered sufficient the options to mitigate flood waters is limited. Raising and extending the existing levee would be possible. It may also be possible to raise Ashwell Road to provide additional flood protection to the south instead of extending the existing levee.

To provide protection from the 100 ARI flood event the existing embankment would need to be raised approximately 200mm plus freeboard (500mm in total). This would affect the Templers Road crossing of the embankment. For costing purposes we have assumed that the levee will be extended adjacent to Ashwell Road rather than raising the road. We have also assumed that the swale recommended by mitigation option 6 will be formed as part of the levee works.

The location of the recommended levee is illustrated in Figure 13.

TABLE 7 ISSUE 5: MITIGATION OPTIONS COSTS

Mitigation Option	Capital Cost ($ GST ex.)
9. Raise and extend levee	350,000

6.6 Issue 6: Increase in Runoff Water from New Development

6.6.1 Mitigations Option 10: Detention requirements in new developments

An increase in impervious area due to development of the Rural Living zoned areas will increase the peak flow and volume of runoff to be managed in Wasleys.

Requiring detention of stormwater flows from new developments will reduce the potential for an increase in flood damage risk and nuisance due to local runoff. Maintaining peak flow rates to their current level will reduce the need for upgrades to existing Council assets in the future.

It is recommended that new developments be required to detain runoff such that predevelopment flow rates are maintained for storms up to and including the 1 in 100 year event.

6.6.2 Mitigation Option 11: Management of surface water for new development between Ashwell Road and Pratt Road

Council has received interest from developers for a rural living residential development on the land between Ashwell Road and Pratt Road. This area lies between two ridges, one runs along the rear of the existing Ashwell Road development and the other runs parallel until it intersects the existing development on the eastern side of Pratt Road. The natural drainage of this land is from southeast to northwest. There is a sizable upstream rural catchment of approximately 100ha (including the land proposed for development). The outlet of this catchment currently drains through the rear of the allotments along Pratt Road and then into the township via the existing stormwater network.

The options for drainage of this area are limited as there is existing development on the downstream side. The current drainage capacity of Pratt Road is also already low on the western side.

Rural Flows

Any development within this area will be required to manage the rural runoff such that any residential development is protected from flooding. The development will also need to convey this rural runoff contribution towards Templers Creek, which is its current destination.

Channelising the rural runoff contribution through the development to Pratt Road is one option. This will protect any new residences from flooding but will also concentrate the flows toward Pratt Road to one location which is likely to cause more nuisance flooding than the current arrangement where the flows are distributed. It is therefore not recommended.

The other option is to form a cut off levee and swale around the south eastern end of the development to direct flows to the east. This would require 'cutting' through the ridge between the proposed development area and Ashwell Road. These flows would need to be managed under the road and into the rural land to the east. The extended flood levee is not expected to extend as far southeast, so such a flow route under the levee would not be required at this point. To manage the water a swale system would need to be constructed to channelize these additional flows and manage their flow path toward Templers Creek on the eastern side of Ashwell Road and the levee. This option could be combined with Mitigation Option 6. It would require the purchase of additional land adjacent to Ashwell Road.

As discussed in section 6.3.2 if these works were completed they would effectively remove the rural runoff contribution from the Ashwell Road basin.

The location of the recommended cut off swale and levee is illustrated in Figure 13.

Urban Flows

The additional runoff generated by the impervious surfaces in any proposed development will need to be managed so that no additional pressure is placed on the current drainage system. As with the rural runoff there appears to be two overall options for management of flows. One is to direct the runoff toward Pratt Road, the other is to direct flows to the Ashwell Road detention basin and subsequently the swale proposed for the eastern side of the flood levee.

For either option the runoff peak flow should be managed such that it is less than or equal to the predevelopment peak flow rate from the area. This will require detention of some form within the development.

If the runoff is directed toward the east pumping will be required from the detention within the development due to the topography. The capacity of the Ashwell Road basin to manage these flows without overtopping should be assessed. This may limit the maximum allowable outflow from the development. The consequences of this approach will be standing water in the retention component of the Ashwell Road basin for longer periods than currently experienced. The peak outflow rate from the basin may also increase and therefore the flow in the proposed swale.

The Pratt Road, road side swales on the eastern side currently have low capacity. Therefore direction of additional flow volumes to these is not recommended. Even if the flows from the proposed development are detained to the predevelopment flow rate there will be additional flow volume introduced to the system. This additional flow volume has the potential to exacerbate any flooding or pooling that occurs as a result of the system's low capacity. Even if this system was upgraded it is still likely to cause nuisance if the duration of flows occurring in the road side system is significantly increased.

The cost of implementing the strategies to manage rural flows as part of mitigation option 11 has been assessed. The cost of managing the urban flows in any new development has not been considered.

The implementation of any works will be subject to development proposals. However given the likelihood of additional flows being directed toward Ashwell Road it may be prudent for Council to ensure any works designed to manage flows around the township include provision for additional flows from development of this area.

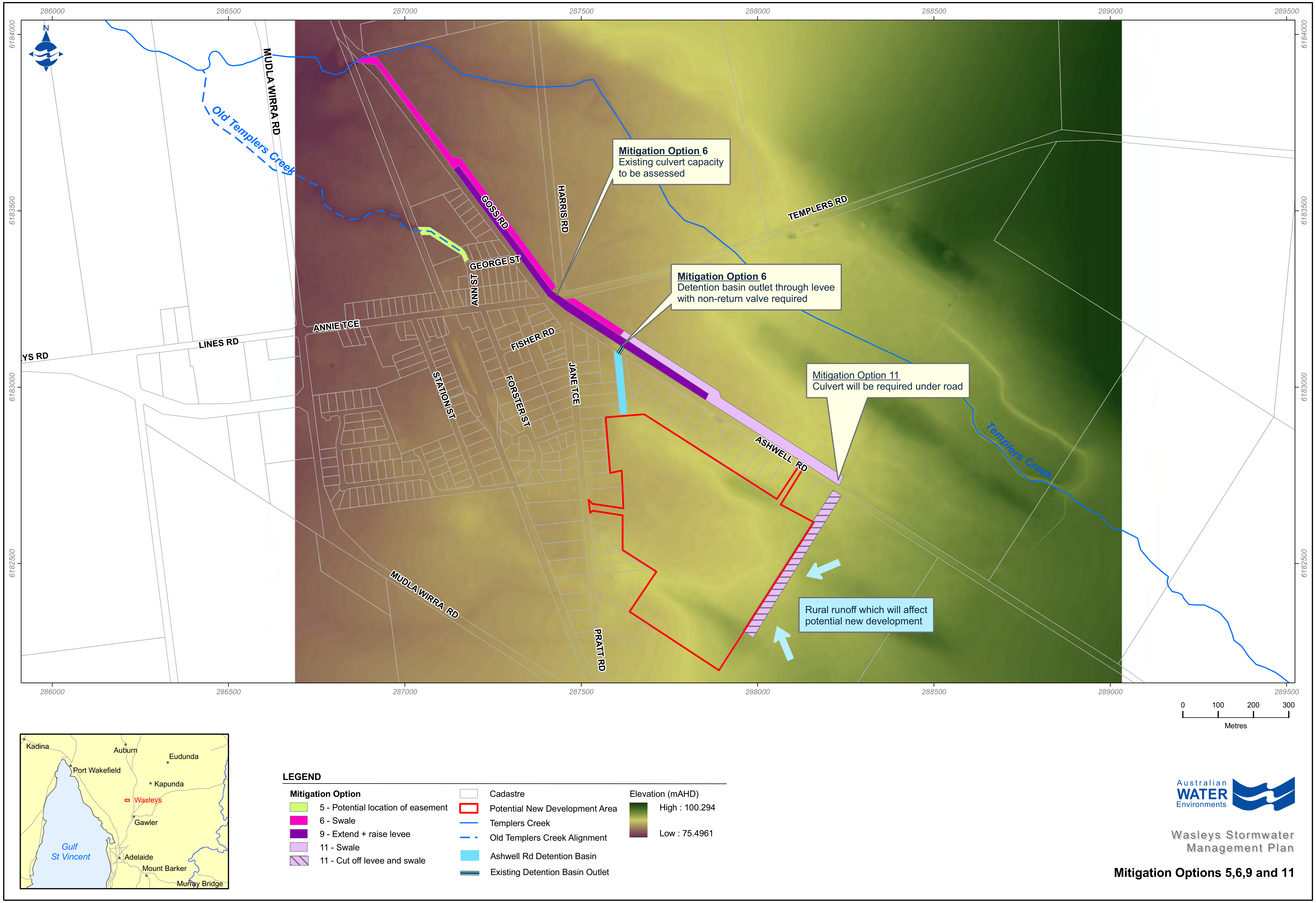
TABLE 8 ISSUE 6: MITIGATION OPTIONS COSTS

Mitigation Option	Capital Cost ($ GST ex.)
11. Cut off levee and swale	109,000

6.7 Issue 7: Effectiveness of proposed Ridley Mill design

The proposed stormwater management system for the Ridley Mill development has been modelled as described in Tonkin (2008). The modelling of the retention basin assumed that at the beginning of a storm the retention basin had a remaining capacity of 3700m^3 as is consistent with the Tonkin (2008) report. This assumption in the Tonkin report is based on the water balance model of the oval basin which they conducted.

Stage 2 of the development was included in the ultimate development model. This model indicates that under the above assumption the retention basin will not overtop during a 100 year ARI rainfall event. As such, for rainfall events less than or equal to 100 year ARI event the development discharges less than the predevelopment runoff rate. Therefore the current design for the development meets the recommendation in Mitigation Option 10.



Mitigation Options 5,6,9 and 11

7 Stormwater Harvesting and Reuse Strategies

The consultation process found that there was a strong desire from the Wasleys' community to explore water reuse opportunities to green public open space. Stormwater harvesting is one way in which this could be achieved. The potential for stormwater harvesting in Wasleys and the indicative cost of such a system is discussed below. There is also the opportunity to include Water Sensitive Urban Design (WSUD) measures to help in 'greening' Wasleys and enhance the use of rainwater tanks on private properties.

7.1 Managed Aquifer Recharge (MAR)

MAR, where viable, can be an attractive option for the storage of stormwater for later reuse. The potential for using MAR depends on the properties of the aquifers in the area, the salinity of the existing groundwater, the likely supply of stormwater, the demand and intended purpose for the harvested stormwater, the availability of land, and potential cost of the project. AGT (2008) investigated the potential for the use of MAR for the storage of stormwater for later reuse within the Light Regional Council area. The report specifically considered the potential in the vicinity of the Wasleys township.

The report found that MAR is not considered viable due to the expected high salinity groundwater and therefore low expected yield of any harvesting system. Whilst the potential for intersecting a bore with a reasonable (+4 L/s) flow rate was considered moderate to good (AGT, 2008) the yield of harvested stormwater was expected to be less than 5ML/yr.

Given the results of the AGT (2008) work, the use of MAR as a storage option within a stormwater reuse project was not considered further.

As such, the stormwater harvesting concept considered surface water storages only.

7.2 Stormwater Reuse Modelling

The potential for stormwater reuse in the Wasleys township was investigated using a Excel based water balance model. The following sections detail the key modelling parameters, the modelling approach and the results of the analysis.

7.2.1 Key Stormwater Reuse Parameters

7.2.2 Demand

The potential uses for harvested stormwater investigated were based on the feedback received from the community. The majority of the feedback supported the provision of stormwater for irrigation purposes at a range of key community sites in the township. Table 9 details the irrigation sites identified and the estimated irrigation demand for each area.

The annual distribution of irrigation demand and the volume of water required for each site were calculated based on the IPOS (2008) methodology. Using this methodology the demand is dependent on the quality of the turf required. The bowling green is likely to have demands which exceed that of other local sports turf areas. As such this site was assumed to have the same demand as areas defined as Premier Sports Turf.

TABLE 9 STORMWATER REUSE IRRIGATION DEMANDS

Sites	Irrigation Area (ha)	Turf Type	Estimated Average Annual Irrigation Demand (ML)
Bowling Green	0.15	Premier Sports Turf	0.53
Oval complex	1.74	Local Sports Turf	4.96
School	0.70	Local sports Turf	2.01
John Wasley Reserve	0.14	Passive recreation	0.26
Totals	**2.73**	-	**7.74**

Figure 14 below illustrates the distribution of total irrigation demand throughout the year. This distribution was used in the water reuse modelling and was based on the IPOS (2008) analysis method which takes into account the monthly evapotranspiration and rainfall. The monthly evapotranspiration information used for the modelling was based on the Areal Potential evapotranspiration on BOM (Bureau of Meteorology) climate atlas. The monthly rainfall statistics were based on the long term averages at the BOM station at Freeling (station number 23325).

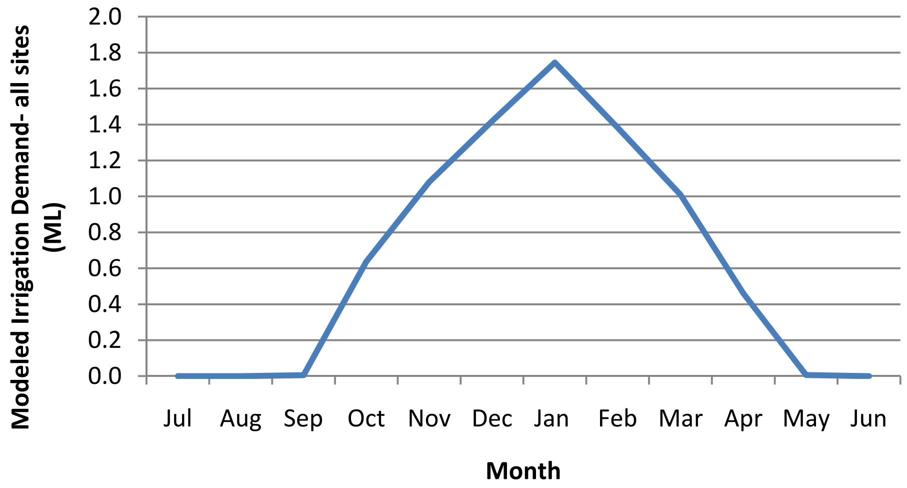


FIGURE 14 MODELLED IRRIGATION DEMAND AVERAGE ANNUAL DISTRIBUTION

The stormwater reuse demand did not include potential demand for a 'third pipe system' to the residential properties to supply toilet flushing or other non-potable needs. These needs were not considered as the cost of retrofitting such systems is significant and the response of the community indicated that providing reuse for irrigating public open space was highly valued.

7.2.3 Stormwater Runoff

The volume of stormwater available for harvesting was modelled using the Hydrological model component of the Water Quality modelling package MUSIC. The catchments for the harvesting were defined by considering the urban catchments defined for the hydraulic analysis. Daily rainfall data for the period 1988-2008 as measured at Freeling (BOM station number 23325) was used as input to the MUSIC model. The runoff was calibrated to achieve a runoff coefficient of 0.15. C= 0.15 was considered a reasonable runoff coefficient for the low density residential development in the urban areas of the catchment where there is a significant proportion of impervious area.

The daily runoff record generated by MUSIC was then used in a Microsoft Excel based water daily water balance model.

7.2.4 Water Balance Conceptual Model and Assumptions

The water balance model was developed based on the following system design:

- An online storage on the old Templers Creek alignment would be constructed. This would capture stormwater flows directly from catchment HC3 (Main Storage) and would provide an overflow route for any spill from this basin into Templers Creek;
- The stormwater flows from catchment HC2 would be directed into the Old Templers Creek alignment by directing flows into the existing stormwater network at the corner of Ann Street and George Street. Analysis of 21 years of daily rainfall in MUSIC indicates that the peak flow to be diverted would be in the order of 11L/s. This could be done by;
    - Capturing flows from the eastern side of Goss Road using a culvert or spoon drain and directing flows into the George Street roadside channel;
    - Capturing flows on the eastern side of Goss Road using a pit to direct flows into the Annie Terrace/ Ann Street underground network. This would require an extension of the underground network along Annie Terrace to the east;
- The basins proposed as part of the Ridley Mill development would be completed and would operate as described in Tonkin (2008). One basin within the development adjacent to Mudla Wirra Road (Ridley Mill Basin) and one basin within the Oval grounds (Oval Basin). The Ridley Mill Basin was assumed to be 5.7ML in capacity with dimensions consistent with the detailed design available. The Oval Basin was assumed to be 2.5 ML in capacity. There was no detailed design available, therefore it was assumed that the basin would be square, 2m deep and 43x43m at the water surface level;
- A pump would transfer water from the Ridley Mill Basin once it reached 1.5ML and pump to the Oval Basin when there was capacity in this basin. I.e. The system would aim to keep the Oval Basin full at all times. The pumping main would be installed as proposed by the design for the subdivision (Stage 2 including the Oval Basin has not yet reached the detailed design stage);
- A pump would transfer water from the Main Storage to the Oval Basin if there was not sufficient water to top up the Oval Basin from the Ridley Mill Basin. The pumping main would be installed in the road reserve along Annie Terrace and Station Street;
- The Oval Basin would act as the distribution point for the irrigation network to the Oval, School, Bowling Club and John Wasley Reserve;
- The system was modelled to preferentially draw down the Ridley Mill Basin instead of the Main Storage as there is no safe overflow route from this basin other than over Mudla Wirra Road to the west. Therefore the volume of water detained in this basin should be minimized.

The following are the key assumptions in addition to the system design that were used to complete the model:

- The pumps from the Main Storage and Ridley Mill Basin to the Oval Basin were indicatively sized to complete the water balance model it was assumed that they operate 12 hrs each day;
- An infiltration rate of 5mm/d was assumed for each of the three basins;
- The water balance modelling was based on the current land use within the study area;
- The geometry of the Main Storage was always square with 1 in 4 side slopes and a maximum depth of 2m.

The conceptual design and location of potential services is illustrated in Figure 15.

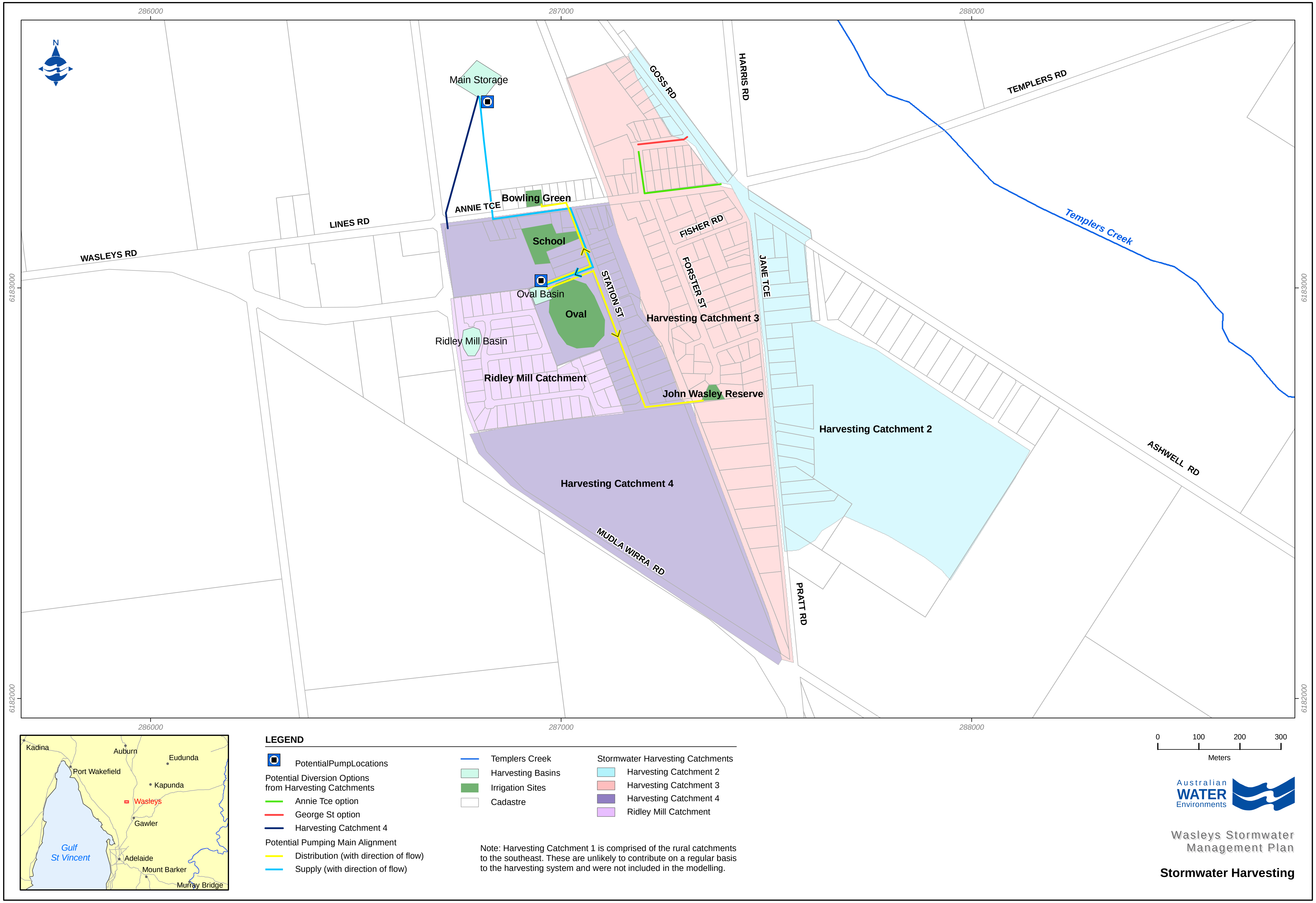


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Figure 15

7.2.5 Sensitivity Analysis and Scenarios Modelled

The conceptual design of the model allowed three variables for analysis, the Main Storage size, the Ridley Mill Pump size and the Main Storage Pump Size.

An analysis of the effect on the system and security of supply of changing pump size was conducted. The pump sizes for each storage are interdependent as the Main Storage Basin pump rate is conditional on the volume of water supplied by the Ridley Mill Basin to the Oval Basin. As such the objective of the sensitivity analysis was not to optimize the pump sizes but to ensure that the Main Storage Size and the resulting security of supply information was based on realistic pump sizes and rates.

Sensitivity analysis of the Ridley Mill Basin found that the annual average spill was 1.3ML with a spill occurring in 33% of years during the modelling period. Increasing the pump rate to the oval basin above 1L/s over 12 hours or 0.04 ML/d did not reduce average annual spill volume. Given the aim of the pump from the Ridley Mill Basin is to manage stormwater from the development whilst minimizing spill to Mudla Wirra Road, the pump rate from the Ridley Mill Basin was set at 0.04 ML/d.

Analysis of the size of the Main Storage Basin pump was conducted. It was found that if the pump rate was at least 5 L/s the security of supply was dependent on the Main Storage Basin size alone and not restricted by the pump rate. Given that a 5 L/s pump is within the range that are readily available the modelling was conducted assuming this pump rate.

Figure 16 illustrates the change in storage volume during the study period for a scenario with basin uncovered and a 9.3 ML main storage volume.

7.2.6 Security of supply curve and covered storage scenarios analysed

The security of supply of a stormwater harvesting system including a surface storage can be significantly affected by losses to evaporation. Two scenarios were modelled which included covering all or some of the three storages to reduce the evaporative loss.

The three scenarios were as follows:

- All Storages with covers;
- All Storages without covers;
- A cover on the Oval Basin only.

TABLE 10 SECURITY OF SUPPLY (PERCENTAGE OF YEARS DEMAND COMPLETELY MET)

	Scenario		
Main Storage Size (ML)	**All Basins Covered**	**No Basins Covered**	**Oval Basin Covered**
2.2	71	38	57
4.1	81	67	71
5.0	90	71	71
9.3	95	67	76
15.5	95	57	67

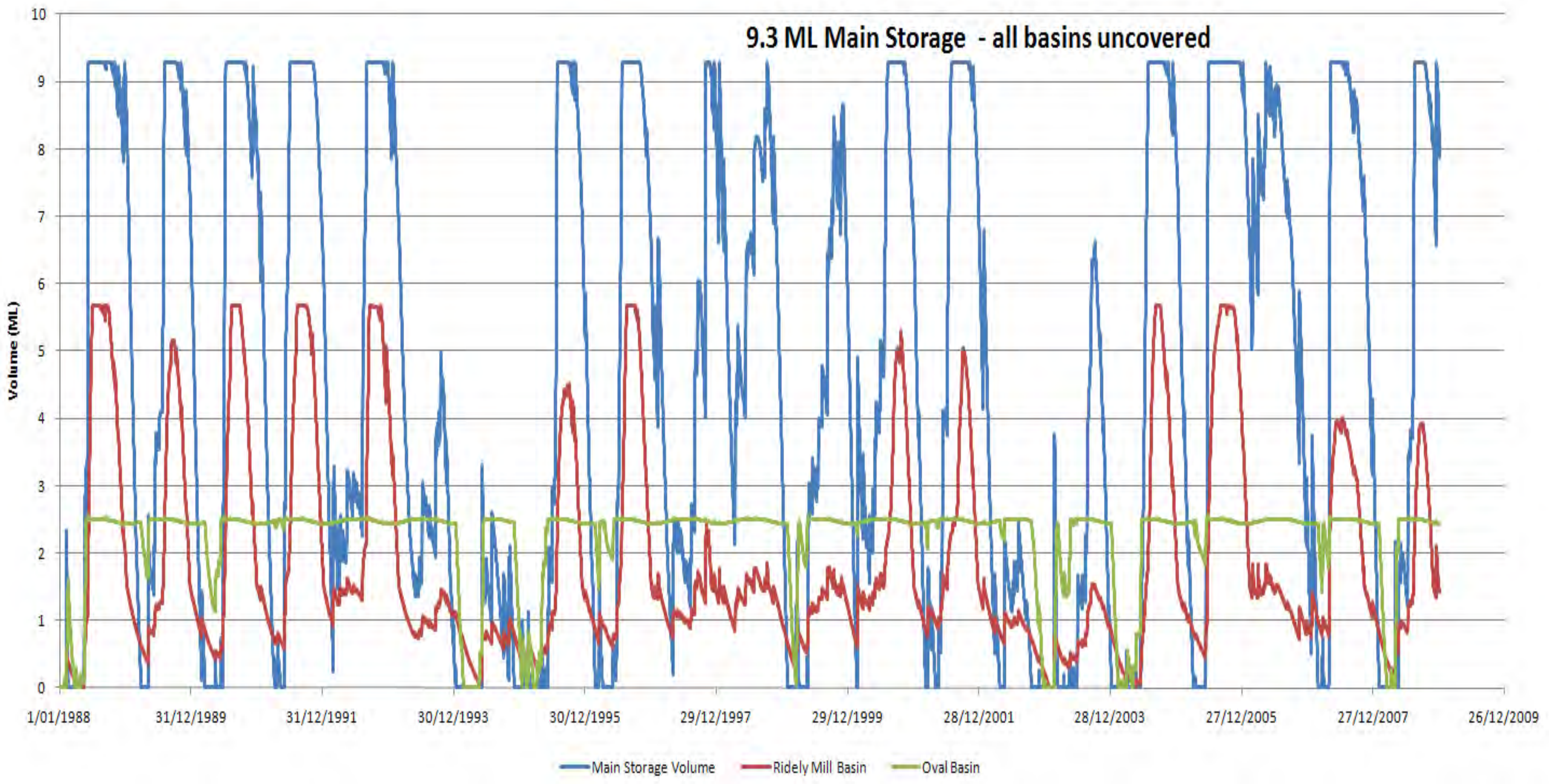

FIGURE 16 MODELLED STORAGE VOLUME THROUGHOUT STUDY PERIOD

7.2.7 Results

Table 10 details the change in security of supply with Main Storage Size and the use of covers on some or all of the storages. The maximum security of supply across all the scenarios ranged between 71-95%. That is demand is met in at least 15 of the 21 years considered in the modelling period.

The maximum security of supply occurs for all scenarios between 5 and 9 ML. The reliability of the system reduces once storages become too big. This is because the infiltration and evaporation losses increase with increasing surface area. Once the benefit of additional storage size to capture inflows is balanced by the increased losses to infiltration and evaporation any increase in storage size causes a reduction in security of supply.

The use of a cover on all or some of the basins increases the security of supply by reducing the losses to evaporation. The increase in security of supply expected as a result of some or all of the basins being covered is between 5-20%. The cost of covering the Oval basin would be in the order of $25,000. Covering all the basins would cost in the order of $120,000.

Assuming a 9.3 ML main basin, no covers and no liners on any of the basins the average annual harvest is 7.3 ML/a with a security of supply of 67% (14 out of 21 years). If the main storage basin was lined (assuming no infiltration occurs) the average annual harvest would be 7.7 ML/a with a security of supply of 95% (20 out of 21 years). That is an increase in security of supply of 28%. Lining the main basin with clay will cost in the order of $190,000. That is approximately $6800 per percentage increase in security of supply.

Covering only the main storage and not lining it will yield an average annual harvest of 7.6 ML/a with a security of supply of 86%. The cost of covering the main storage would be in the order of $65,000. That is approximately $3,200 per percentage increase in security of supply. As discussed above the cost of covering the oval basin alone would be in the order of $25,000. Covering only the oval basin increases security of supply by approximately 10%. That is approximately $2,400 per percentage increase in security of supply.

Therefore there is greater cost benefit for covering the basins than in lining them in terms of security of supply achieved. There is also greater return, in terms of security of supply, in investing in covers for the oval basin, than the main storage basin or all the basins.

Increasing the depth of the basins will also increase security of supply by reducing the surface area to volume ratio and thus the area exposed to evaporation. The effect of increasing basin depth has not been assessed for this study. Constraints on increasing storage depth would include, batter slope requirements, safe access requirements and excavation and disposal costs. The optimum basin size and geometry including depth would need to be confirmed as part of detailed design of the system.

The final design will be dependent on Council's design objectives including their needs with respect to security of supply and other factors.

7.2.8 Water Reuse Summary

The results of the modelling indicate that a reasonable security of supply could be expected for a stormwater harvesting system developed in the Wasleys township. It is possible that for the years in which the demand could not be completely met a less than ideal water regime could be implemented at all sites to enable at least some irrigation to continue through until the winter months.

7.3 Other 'greening' Options

There is some potential for the installation of small scale Water Sensitive Urban Design measures to 'green' the main street of Wasleys, in particular Annie Terrace. However the established nature of the street trees and the limited space between the footpath and the roadway restricts the options. In general Water Sensitive Urban Design principles are reflected in the Council's Development Plan. Ensuring these inclusions reflect current Water Sensitive Urban Design best practice will assist with water efficient features being incorporated in new and infill development.

7.3.1 Street Trees

There are established street trees along Annie Terrace. It would be difficult to make changes to the kerb arrangement near these trees to increase the volume of water infiltrating adjacent to the tree without damaging the root system. In the case of established trees, where the base of the tree is well above the kerb invert the options are limited to infiltration near the tree. Infiltration options also have the potential to clog.

It is therefore recommended that Council investigate the use of kerb break tree watering when considering the installation of new or replacement street trees in Annie Terrace. A key issue when using kerb break tree watering is managing the step down between the top of kerb /footpath level and the level of the base of the tree at kerb invert height. This can be managed using a grate or barrier around the tree.

As this option is opportunistic it a cost estimate has not been derived. This option is not considered further in the cost/benefit and priority analysis.

7.3.2 Additional planted beds

There is potential for additional planted beds between the footpath and the kerb along Annie Terrace. The additional beds could be placed in selected locations where the verge offers sufficient distance between the kerb and footpath.

The beds would need to be planted such that the levels matched that of the footpath. A grate could be installed in the base of the adjacent kerb and an 'AG' pipe in a gravel trench extended from the grate under the plantings to provide flows after storm events.

Potential issues associated with the installation of such planting areas would be clogging of the gravel trench and 'AG' pipe over time and potential for nuisance due to standing water in the voids within the gravel trench for extended periods of time during winter.

The advantages of providing additional planted beds would be aesthetic providing additional 'green' spaces along the main street and would take advantage of stormwater flows which are currently not utilized.

The estimate cost of installing additional planted beds with described watering method, assuming 4 beds of 4.5m^2 is presented in Table 11.

TABLE 11 ADDITIONAL PLANTED BEDS COST

Mitigation Option	Capital Cost ($ GST ex.)
Stormwater Reuse System	15,000

7.4 Rainwater Tanks

The use of rainwater tanks for toilet or garden usage provides an opportunity to reduce reliance on potable water supplies, the reliance on Murray River flows and provides some reduction in the annual volume of stormwater managed by the stormwater management system.

Council's Development Plan encourages the collection of roof run-off in rainwater tanks and the provision of at least one tank of 5000 litres per dwelling, which is larger than the state wide minimum requirement. The Development Plan also indentifies the use of rainwater for domestic purposes, the need to direct roof run-off onto garden areas, and that landscaped areas and parking areas should be designed to facilitate stormwater infiltration on-site.

During the community consultation for the SMP, it was indicated that many people already have rainwater tanks in Wasleys.

The potential for enhanced uptake of rainwater tanks within Wasleys, in addition to the existing use and requirements will be dependent on educational activities by Council and continued updating of the development plan to reflect best practice rainwater harvesting practices. The cost of rainwater harvesting systems on private land are generally covered by the landowner, as such no cost has been estimated for uptake of this technology. This water reuse strategy has not been considered further in the cost/benefit, priority analysis in section Table 9.

7.5 Water Reuse Recommendation and Cost Estimates

An indicative cost estimate for the construction of the stormwater harvesting system proposed was completed and is summarized in Appendix D. The following key assumptions where made in the cost estimation:

- No design costs where included;
- A 9.3ML basin size has been assumed as this maximizes the possible yield from a balancing storage perspective;
- The oval basin will be covered. As discussed in section 7.2.7 the return with respect to security of supply is greater for an investment in covering all or some of the basins rather than lining them. The modelling has also shown the largest return with respect to security of supply on investing in basin covers occurs when the oval basin is covered;
- The construction of the oval basin and all irrigation systems and associated distribution pumps are completed as part of Stage 2 of Ridley Mill or otherwise;
- The diversion from Harvesting Catchment 2 – George St option is adopted and a swale would be constructed for diversion of Harvesting Catchment 4 flows. The diversion of flows from Harvesting Catchment 2 along George St is the most cost effective option and has been adopted in the costing. There is the potential for additional nuisance issues to occur

due to ponding stormwater flows and the duration of standing water in the road side swale as a result of directing greater volumes of water along this surface drainage path.

The estimate capital cost is $620,000.

8 Water Quality Assessment

Stormwater generated within the Wasleys township under the current stormwater management system discharges at four main points. Figure 15 illustrates the four major catchments within the township. The four major catchments include:

1. Harvesting Catchment 2- discharges to Goss Road to the north,
2. Harvesting Catchment 3- discharges to the old Templers Creek channel,
3. Harvesting Catchment 4- discharges to Lines Road to the west, and
4. Ridley Mill Catchment- discharges to the retention basin within the development and in large rainfall events to Mudla Wirra Road drainage system.

The receiving environments for the flows is the road reserve in the case of Goss Road, Lines Road and Mudla Wirra Road. Here the flows will pond, evaporate and slowly infiltrate after rainfall events. Harvesting Catchment 3 discharges to the old Templers Creek channel which meets the main Templers Creek channel north of the township. Templers Creek is an ephemeral watercourse which is significantly altered from its natural conditions. The main channel of Templers Creek downstream of Wasleys passes through cleared agricultural land. There is little or no remaining remnant vegetation within the channel and therefore limited remnant dependent aquatic ecosystems that will be effected by the quality of runoff from the township. With the exception of large flow events, the stormwater flows from Wasleys are expected to infiltrate and evaporate within a short distance from entering the main Templers Creek channel.

Indicative water quality contaminate levels were derived for the four main discharge points from the township. The results are summarized in Table 12. The water quality characteristics were derived using a daily time step MUSIC model with 21 years of rainfall data (BOM station at Freeling - station number 23325).

The average annual flow from the catchments was calibrated such that the runoff coefficient was 0.15. C=0.15 is considered an appropriate runoff coefficient for the rural residential catchment. The base and storm flow parameters for what is primarily rural residential development were taken from Brisbane City Council (2003). No other flow or water quality information was available as the basis for calibration.

TABLE 12 INDICATIVE WATER QUALITY CHARACTERISTICS

Discharge Point	Total Suspended Solids		Total Phosphorus		Total Nitrogen	
	Mean Conc. (mg/l)	Mean Annual Load (kg/yr)	Mean Conc. (mg/l)	Mean Annual Load (kg/yr)	Mean Conc. (mg/l)	Mean Annual Load (kg/yr)
Goss Road	28.7	1410	0.054	1.51	0.513	11.5
Templers Creek	24.6	2110	0.153	5.76	1.81	50.8
Lines Road	25.3	1400	0.153	3.77	1.79	31.6
Ridley Mill Basin/ Mudla Wirra Road	23.8	759	0.149	2.10	1.77	18.9

The results indicate that it is unlikely that water quality from the township is having any detrimental impact on downstream ecosystems.

9 Recommended Works and Further Investigations

This section provides a summary of the recommended capital works and further investigations, including comparison of the estimate costs, benefits and discussion of timeframe and priority.

9.1 Summary of Priority, Timeframe, Cost and Benefit

Table 13 summarises the recommended works and further investigations. It details the estimated capital and recurrent costs and the recommended timing for implementation of the recommendations. The recommended timeframes for implementation were derived from consultation with Council. These timeframes indicate the relative priority of each of the recommendations. The recommendations have been presented in priority order.

Table 13 also presents the benefits of completing the recommended works or further investigations. The benefits are divided into flood mitigation, water harvesting and water quality benefit. At the bottom of the table the criteria used to score against these benefits are described.

Whilst the timing of each of the recommendations has been indicated separately there is potential for cost savings to be gained from combining the implementation of some of the recommendations. This includes Option 9 (and Option 6) which call for extension and raising of the existing levee and the stormwater reuse system which includes excavating a large storage. There is potential for cost savings to be realised in the disposal of spoil from the basin and procurement of materials to complete the levee. The practicality of whether these cost savings can be realised is dependent on the availability of funding for one or both of the projects and the relative benefit to the community of implementing both recommendations.

Appendix D provides details of how the cost estimates for the mitigation options involving capital works were derived. Appendix F provides a summary of the recommended works and further investigations with selected mitigation options broken into sub projects which reflects the way in which Council is likely to implement some of the works

9.2 Potential Funding Arrangements

Council has a structure infrastructure investment program. Many of the works proposed will be included within this program. There is also the potential of Council to secure funding from the Stormwater Management Authority, in particular for the works relating to the management of floodwaters from Templer's Creek. There is also the potential for federal government funding for works under various programs.

TABLE 13 SUMMARY OF RECOMMENDED WORKS AND FURTHER INVESTIGATIONS

Project/ Activity Title	Investigation Cost ($)	Capital Cost ($)	Recurrent Cost ($ pa)	Recommended timing (yrs)	Flood Mitigation Benefit				Water Harvesting Benefit			Water Quality Benefit			Other Benefits	
					Score	Measure Used (D) - AAD Reduction (P) - Properties Affected (Q) - Qualitative	Quantification or Description of Benefit	Cost Benefit Ratio	Score	Measure Used (V) - Volumetric (Q) - Qualitative	Quantification or Description of Benefit	Score	Rating (H) - High (M) - Medium (L) - Low	Qualitative Description of Benefit	Rating (H) - High (M) - Medium (L) - Low	Qualitative Description of Benefit
Option 4 Localised sag issues. Inspect individual sites and complete appropriate mitigation	4,000			3	3	P (~13)	Approximately 13 properties immediately adjacent to local sags but the impact would affect general motorists									
Option 5 Nuisance flooding of private land. Consider purchasing and easement from George St	3,000			3	3	P (1)	One property affected, corner of Ann and George Streets									
Option 7 Low capacity roadside swales. Investigate options for increasing swale capacity	6,000			3	4	P (48)	48 properties adjacent to roadside swales with less than or equal to 2 year ARI capacity									
Option 6 Nuisance flooding of private land. Construct swale from detention basin outlet to Goss Road		Cost included in Option 9		7	1	P	Management of urban and rural flows from Ashwell Road development and adjacent rural land away from private agricultural land									

Project/ Activity Title	Investigation Cost ($)	Capital Cost ($)	Recurrent Cost ($ pa)	Recommended timing (yrs)	Flood Mitigation Benefit				Water Harvesting Benefit			Water Quality Benefit			Other Benefits	
					Score	Measure Used: (D) - AAD Reduction (P) - Properties Affected (Q) - Qualitative	Quantification or Description of Benefit	Cost Benefit Ratio	Score	Measure Used: (V) - Volumetric (Q) - Qualitative	Quantification or Description of Benefit	Score	Rating: (H) - High (M) - Medium (L) - Low	Qualitative Description of Benefit	Rating: (H) - High (M) - Medium (L) - Low	Qualitative Description of Benefit
Option 9 Regional Flooding. Raise flood levee and form swale	20,000	350,000	7000	7	5	P (township)	The entire township may be affected by floodwaters if the levee fails. A small number of private land parcels will realise benefits from better stormwater management									
Option 11 Increase in runoff from new development. Cut off levee and swale	10,000	109,000	2,500	7	3	P (18)	Provide flood protection for new rural living development (18 properties) and existing residences									
Option 3 Driveway crossovers and water ponding in swales. Provide cement treated driveway cross overs		116,000	5,500	10	5	P (108)	Properties provided with driveway crossovers									
Other greening options. Additional Planted Beds		15,000	1,000	10											M	Greening of main street will provide aesthetic benefits

Project/ Activity Title	Investigation Cost ($)	Capital Cost ($)	Recurrent Cost ($ pa)	Recommended timing (yrs)	Flood Mitigation Benefit				Water Harvesting Benefit			Water Quality Benefit			Other Benefits	
					Score	Measure Used: (D) - AAD Reduction (P) - Properties Affected (Q) - Qualitative	Quantification or Description of Benefit	Cost Benefit Ratio	Score	Measure Used: (V) - Volumetric (Q) - Qualitative	Quantification or Description of Benefit	Score	Rating: H) - High (M) - Medium (L) - Low	Qualitative Description of Benefit	Rating: (H) - High (M) - Medium (L) - Low	Qualitative Description of Benefit
Stormwater reuse and harvesting strategies Water Reuse System		620,000	5,000	10					2	V	Harvesting demand for local green spaces 7.7 ML/a				M	Strong Community support for provision of irrigation water for oval

Flood Mitigation Scoring System			
Score	Reduction in average annual flood damage (AAD) $	Number of Properties Affected	Score
5	> $100k	>50	5
4	$50k - $100k	25 - 50	4
3	$20k - $50k	10 - 25	3
2	$10k - $20k	5 - 10	2
1	< $10k	<5	1

Water Harvesting Scoring System		
Volume of Stormwater Harvested (ML)	Benefit of Re-use	Cost Benefit Ratio
>100	High level of use for existing Reserves & Community Land, future Reserves and Residences	>1
50 - 100	High level of use for existing Reserves & Community Land, future Reserves	0.75 - 1
25 - 50	Meets demands for existing Reserves and Community Land, but not future areas	0.5 - 0.75
5 - 25	Meets demands for localised area only	0.25 - 0.5
<5	Does not fully meet demands for localised area but has other beneficial result	0 - 0.25

10 Summary

A range of objectives for the Wasleys Stormwater Management Plan were identified through consultation with the community and discussions with the project steering committee. The Stormwater Management Plan has addressed these objectives through the use of hydrological, hydraulic and water balance modelling and by considering the anecdotal evidence available regarding the performance of the system.

Understanding the system

The Stormwater Management Plan has met the objective to better understand the drainage system by conducting and providing the results of a range of hydrological and hydraulic analyses. The analysis has shown that the formal drainage infrastructure is of sufficient capacity. The informal drainage infrastructure which forms the majority of the drainage network has varying capacities. A significant proportion of the roadside swales were found to be of low capacity. The potential for flooding damage as a result of the low capacity roadside network was quantified. In at least three streets in the study area there is potential for stormwater flows to enter private property and potentially inundate buildings.

The performance of the current stormwater management system under the ultimate development scenario was also assessed. Whilst there was an increase in runoff, particularly during higher return period storms the change in the reliability of the system was small. The potential for flooding of private property would however be exacerbated by additional flows through roadside swales which currently have low capacity.

Deficiencies in the existing stormwater management system that could not be modelled hydraulically were also identified. These issues included the management of an overland flow path through private land, the location of localized sag areas within the road network and the nuisance caused by ponding and damage to roadside swales at driveway crossovers. The management of rural runoff originating from the south eastern side of the township was also considered.

Develop strategies to alleviate existing problems

A range of mitigation strategies are recommended. These strategies include:

- Providing formalized driveway crossovers. Three methods of achieving this have been provided;
- Undertaking assessments of localized sag issues to determine the site specific requirements;
- Purchasing an easement at the corner of Ann Street and George Street to enable better management of overland flows during large rainfall events;
- Undertaking additional assessments of road side swales of specific concern to determine site specific options for increasing capacity;
- Enforcing a minimum finished floor level for new buildings above natural surface levels;
- Requiring new developments to require detention of stormwater such that predevelopment flow rates are maintained for storms up to and including the 1 in 100 ARI event;

- Providing options for management of stormwater within the area between Ashwell Road and Pratt Road which is zoned as Rural Living. This discussion also addressed the need for management of rural flows entering this area;
- Providing a flow path on the eastern side of the flood levee to manage flows from the Ashwell Road detention basin and runoff generated on Ashwell Road itself to prevent nuisance on private land.

Identify potential opportunities for reuse of stormwater

The community desire to 'green' Wasleys and provide irrigation water for the town oval was strongly expressed during the community consultation. A previous study has found that MAR is not likely to be viable in Wasleys. As such, the stormwater harvesting concept developed considered surface water storages only.

Two methodologies were investigated for stormwater reuse in Wasleys. The first involved harvesting stormwater from the residential catchment and utilising the existing Ridley Mill development retention basin, the already proposed Oval Basin and providing an additional harvesting basin along the old Templers Creek alignment. The results indicate that a reasonable security of supply could be provided from such a harvesting system to supply the Oval, School, Bowling Green and John Wasley reserve with irrigation water.

There is also potential for minor stormwater reuse through watering of new or replacement street trees in Annie Terrace and the development of additional plant beds along the main street. The potential for street tree and planting watering is limited due to the generally limited space between the footpath and the kerb and the levels of the existing plantings.

The use of Rainwater Tanks was also identified as a cost effective method of reducing demand on potable water supplies and reducing runoff volumes. Council's existing requirements strongly support reuse using this approach.

Assess the flood risk from Templers Creek

The community have expressed concern about the potential for flooding of new developments by flows from Templers Creek and the capacity of the existing levee. A 1 Dimensional floodplain model was constructed and the estimated flood extent of the 100 ARI event mapped. The analysis found that the existing levee and Ashwell Road to the south are expected to be overtopped during a 100 ARI event. Similar results were found for a 50 ARI event. During a 20 ARI event the existing levee is expected to provide protection to the town. Ashwell Road is also not expected to be overtopped in a 20 year event.

The additional height of the levee required to protect the town from a 100 ARI event was discussed. The modifications to the levee have the potential to be incorporated with the mitigation strategy for managing the outflows from the Ashwell Road detention basin and any works completed to direct rural runoff around any development between Ashwell Road and Pratt Road.

11 References

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